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ABSTRACT

This directory represents the start of a research program directed towards the creation of a human abilities matrix which cross-references data on real world jobs, laboratory performance tasks, and human performance models. The matrix will use the "abilities requirements approach" as the unifying element among these three dimensions. The present effort compiles and cross-references information on computer-based performance assessment batteries and models/theories of human performance. Data from 10 batteries, 123 tasks, and 7 models have been included. For the performance batteries, this information includes availability/acquisition details as well as computer hardware and software characteristics. This document, then, enables researchers to quickly access such data as well as to ascertain those areas in which a paucity of data exists. In general, it appears that current computerized performance batteries emphasize measurement of those characteristics which are most readily measured by computer, without regard for the applicability of such measurement to enhancement of real-world tasks. In particular, a dearth of laboratory tasks with which to assess certain cognitive abilities was noted. This deficiency is regarded as particularly critical in light of the increased reliance on such abilities for performance on modern military and civilian jobs. Difficulties encountered and recommendations for future efforts are presented. (Author/RR)

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NAVAL TRAINING SYSTEMS CENTER
ORLANDO, FLORIDA

HUMAN PERFORMANCE TASK BATTERIES AND MODELS: AN ABILITIES-BASED DIRECTORY

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CENTER OF EXCELLENCE
FOR SIMULATION AND
TRAINING TECHNOLOGY

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ORLANDO, FLORIDA

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HUMAN PERFORMANCE TASK BATTERIES AND MODELS: AN ABILITIES-BASED DIRECTORY

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The present effort compiles and cross-references information on computer-based performance assessment batteries and models/theories of human performance. Data from ten batteries, one hundred twenty-three tasks, and seven models have been included. For the performance batteries, this information includes availability/acquisition details as well as computer hardware and software characteristics. This document, then, enables researchers to quickly access such data as well as to ascertain those areas in which a paucity of data exists.

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Difficulties encountered and recommendations for future efforts are presented.

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In general, it appears that current computerized performance batteries emphasize measurement of those characteristics which are most readily measured by computer, without regard for the applicability of such measurement to enhancement of real-world tasks. In particular, a dearth of laboratory tasks with which to assess certain cognitive abilities was noted. This deficiency is regarded as particularly critical in light of the increased reliance on such abilities for performance on modern military and civilian jobs.

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I. Introduction

A. Performance Batteries

With the increased availability of inexpensive yet powerful microprocessors has come an increasing number of computer-based human performance evaluation devices. These devices typically take the form of a series of tasks designed to assess human functioning in one or more areas such as information processing, perceptual-motor skills, and mood.

Current computer-based performance assessment batteries may include or may have evolved from task elements which existed previously in paper and pencil form (see e.g., the Criterion Task Set--CTS); as non micro-based batteries (e.g., the Multiple-Task Performance Battery--MTPB); or as other micro-based batteries (e.g., the Unified Tri-Services Cognitive Performance Assessment Battery--UTC-PAB). They may have been created to assess performance under a specific set of environmental conditions such as ship motion simulation (Naval Computerized Cognitive Test--CCT); to examine the effects of particular circumstances such as aging (Information Processing Performance Battery--IPPB); or to assess an individual's functioning in a specific area such as grammatical reasoning (Criterion Task Set--CTS).

In general, computerized performance assessment batteries are both inexpensive and readily available to the scientific community. The Taskmaster system software, for example, is available free of charge to individuals who forward two blank floppy disks to the Taskmaster creators at NIOSH (National Institute of Occupational Safety and Health). One purpose of the present work is to catalog this arrray of assessment tools with respect to their origins, intended purposes, and/or hardware and software characterisitics. By so doing, we hope to provide not only a useful comparative index, but also to make clear those areas of human performance measurement which may be either too well- or too little-represented in existing batteries.

A second goal of the present effort is to catagorize each battery's task elements using Fleishman & Quaintance's (1984) "abilities" as the common language. These abilities, then, become the focus of comparison between/among the elements of the various task batteries. Reference to the **Ability Catalog** (Section II B) and the listed ability of "Response Orientation", for example, provides the information that six separate batteries and a total of thirteen individual task elements provide a primary assessment of response orientation. Reference to the ability "Information Ordering", on the other hand, indicates that none of the evaluated battery components require use of this ability. All ability designations were made with reference to the list and descriptions of human abilities set forth by Fleishman & Quaintance (1984, Appendices B and C).

The indicated relation of a specific ability to the task that best assesses that ability is made on the basis of expert judgement. These initial categorizations serve the exploratory nature of the present work.

However, in some cases a particular task is a direct "pure" measure of an ability, while in others the task is only marginally related to a listed ability. Such issues, including the extent to which these tasks actually measure a specific ability, should be the subject of further quantitative analysis.

B. Performance Models

The second area of interest herein is that of "models" of human performance. In some cases these models offer a broad, possibly graphic conceptualization of human performance (e.g., Braune & Foshay, 1983), while others may quantitatively represent specific human behaviors under specific performance conditions (see, e.g., Wherry & Curran, 1966).

Meister (1985) has distinguished between "theories of behavior" and "behavioral models". He asserts (p. 119) that the former are intended to describe functional relationships, are judged by their validity, and may make reference to "intervening variables with tenuous dimensions, such as motivation". The latter are used to predict behavior, are evaluated according to their utility, and their relationship to other variables "must be quantifiable to some degree". The present work disregards such distinctions in order to include sufficient data to permit the creation and subsequent evaluation of the present *Directory* approach. That is, behavioral models and theories of behavior are both deemed relevant and important dimensions of the current effort, and it is not important to distinguish between them at this early stage in our research program.

The third goal of the present work is to assign appropriate ability designations to these human performance "models" in order to enable researchers to effectively incorporate relevant performance theory information in investigations which use a performance battery. By again referring to the **Ability Catalog**, one may see that the "Information Ordering" and "Response Orientation" ability catagories are represented by two and five models, respectively. Ability based inter-battery and inter-model comparisons are, therefore, possible as are model-to-battery and battery-to-model searches.

C. Abilities

An extensive history, dating back to the early Greeks, of the use of ability catagories in the study of human behavior is provided by Dunnette (1976) for the interested reader. Of importance here is Dunnette's assertion (p. 495) that it is the *abilities requirements approach* which affords the conceptual link between the work and test worlds of behavioral taxonomy. Although not considered to be a universally ideal taxonomy (see, e.g., Companion & Corso, 1982), it is this linking capability which makes Fleishman's taxonomy the ideal candidate for use in a research program seeking to "link" theoretical models, task batteries (test), and real-world jobs (work). While other definitions are in use (see Dunnette, 1976, for a discussion of this issue), we will adopt Fleishman's characterization of an ability as a general trait of an individual which relates to his/her performance capacity on a variety of tasks.

This abilities requirements approach represents "a longstanding program of research" conducted by Fleishman and his associates over the past two decades in order to define the fewest ability catagories which are associated with performance on the widest variety of tasks (Fleishman & Quaintance, 1984). In theory, a task can be described by the human abilities required for performance on that task. For example, it may be determined that the task "navigate ship" requires the abilities "Mathematical Reasoning", "Spatial Orientation", and "Far Vision". Consequently, performance on related tasks can be predicted by ascertaining an individual's level of competance in applying or using these required abilities.

Using this prodedure, a researcher can examine the effect(s) of a particular environmental stressor on specific task abilities. For example, the researcher may find that chemical defense protective clothing restricts the ability of "Far Vision". Degradation of performance on specific tasks can then be derived by profiling these tasks according to the required abilities, and generalizing from the stressor/ability degradation database. Thus, to the extent that a task involves "Far Vision" one can estimate the task degradation under specific environmental conditions. This, of course, simplifies a number of issues, not the least of which involves reliably relating abilities to corresponding measures or tasks.

A heuristic entry point into the classification of abilities is to present a classification in terms of broader descriptors or ability *domains*. Drawing on the work of Berliner, Angell, & Shearer (1964), we have categorized human performance into five types of processes (see Table 1). This classification scheme allows one to identify any number of specific behaviors (e.g., scans) as an instance of a broader category of activities (e.g., attends to sensory information) that compose an ability process (e.g., perceptual). This provides a shorthand method in which one can quickly categorize a particular behavior of interest.

There are five major ability domains under which these behaviors are subsumed. This taxonomy allows one to discriminate between types of abilities as; for example, those associated with cognitive versus physical tasks. However, researchers have argued that these categories are not unitary. In other words, two cognitive abilities such as "Memorization" and "Time Sharing" may be as different from one another as they are from those required in performing a physical task. Thus, classificatory systems based on such broad categories may not allow dependable predictions to be made of performance from one task to another. Greater specificity may be gained by breaking down these categories into a limited number of abilities, which should account for most of the variability in task performance. Fleishman and Quaintance (1984, Appendix B) have presented fifty-two such abilities, and in Table 2 these have been grouped into the five ability domains from Table 1.

Table 1. Ability Domain Characteristics

PROCESSES	ACTIVITIES	BEHAVIORS
Cognitive	encodes, stores, acts on, or retrieves information; problem solving	compares, selects, chooses, counts, estimates, searches, analyzes, decides, calculates
Communication	interacts with others	reads, writes, talks, asks, listens, directs, instructs, coordinates, requests, leads, transmits
Perceptual	attends to, searches for, or identifies sensory information	scans, observes, tracks, receives, detects, locates, monitors, recognizes
Physical	uses body power or movement	moves, walks, runs, lifts, twists, jumps, places, carries, balances
Psychomotor	makes coordinated, manipulative, repetitive or precise movements defined by speed and accuracy	handles, manipulates, turns, adjusts, connects, aligns, positions, depresses, tunes

Table 2. Classification of Fleishman's Abilities into Ability Domains

- COGNITIVE
  - Category Flexibility
  - Deductive Reasoning
  - Flexibility of Closure
  - Fluency of Ideas
  - Inductive Reasoning
  - Information Ordering
  - Mathetical Reasoning
  - Memorization
  - Number Facility
  - Originality
  - Perceptual Speed
  - Problem Sensitivity
  - Selective Attention
  - Spatial Orientation
  - Speed of Closure
  - Time Sharing
  - Visualization

- COMMUNICATION
  - Oral Comprehension
  - Oral Expression
  - Speech Clarity
  - Speech Hearing
  - Written Comprehension
  - Written Expression

- PERCEPTION
  - Auditory Attention
  - Depth Perception
  - Far Vision
  - General Hearing
  - Glare Sensitivity
  - Near Vision
  - Night Vision
  - Peripheral Vision
  - Sound Localization
  - Visual Color Discrimination

- PHYSICAL
  - Dynamic Flexibility
  - Dynamic Strength
  - Explosive Strength
  - Extent Flexibility
  - Gross Body Coordination
  - Gross Body Equilibrium
  - Stamina
  - Static Strength
  - Trunk Strength

- PSYCHOMOTOR
  - Arm-Hand Steadiness
  - Control Precision
  - Finger Dexterity
  - Manual Dexterity
  - Multilimb Coordination
  - Rate Control
  - Reaction Time
  - Response Orientation
  - Speed of Limb Movement
  - Wrist-Finger Speed

D. The Research Program

A research program which was in some ways conceptually similar to that described here is that of Allen, Rose, & Kramer (1978). They defined nine *information processing operations* and evaluated the extent to which these operations were used in performing each of the eight tasks comprising their non-computerized Information Processing Performance Battery*. They report, for example, that performance of "Mental Addition" requires use of *transformation, storage*, and *retrieval* operations. On the other hand, use of their operations/task matrix in inverse fashion reveals that *abstraction* is brought to bear only in their "Sentence Recall" and "Sentence Recognition" tasks. The stated rationale for adopting such an approach is that "...individuals can potentially be characterized in terms of parameters derived from models of selected information processing tasks" and that a battery of such tasks "...would not only be potentially predictive of performance on a wide variety of real-world tasks but would also be firmly based in theory" (Allen, et al., 1978).

Goldstein (1980), following a comprehensive review, has concluded that "...no procedures exist that empirically establish the content validity of a training program based upon a match of relevant tasks on the job and in the training program. Further, Fleishman & Quaintance (1984) note that "tasks selected in laboratory research often are not based on any clear rationale about the class of task or skill represented". The taxonomy of human abilities set forth by Fleishman & Quaintance (1984, Appendix B) is thought to provide the common language and evaluative criteria through which these three areas (i.e., jobs, laboratory tasks, training programs) can be cross-referenced and cross-utilized. While this taxonomy is but one of many available, it was chosen for use here primarily because of the specificity of catagorization it affords--i.e., fifty-two identified abilities.

The present work adds performance theory and/or model information to the performance battery user's data bank, and the proposed follow-on efforts would provide human ability requirements of actual shipboard or other real-world tasks to be added to this data bank through traditional task analytic endeavors (see, for example, Peterson & Bownas, 1982). This research program, then, enables formulation of a *job--performance model--laboratory task matrix* which uses catagories of human ability as the common "language" among these three dimensions, and takes advantage of the aforementioned linking capability of the abilities requirements approach. Such a system when fully implemented would, for example, enhance training systems development by providing in one document the key human characteristics (i.e., abilities) required for performance on a real-world job, along with the basic theoretical information necessary to understand that particular type of performance (i.e., models/theories), and the appropriate tools (i.e., laboratory tasks) required to study or train performance on that task, thereby increasing the efficiency of the training process.

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* Note: this "IPPB" is unrelated to the Wickens, et al. (1985) computerized battery of the same name (see Section II C).

In Section II B--the **Ability Catalog**--Fleishman's fifty-two abilities are presented and defined in alphabetical order and, in most cases, Navy-relevant job examples are provided. Following this, the microcomputer batteries (in boldface) and tasks which tap or assess each ability are detailed along with the human perfromance models/theories deemed relevant for that ability. For example, the ability "Spatial Orientation" can be measured by the Maze Tracing task on the IPPB battery, and the Wickens (1980a) Multiple Resource Model detailed in SectionII D may offer some theoretical information related to this ability. For certain abilities, particularly those in the *Physical* domain such as"Dynamic Strength", a suitable non-computer based assessment task is specified (e.g., push-ups).

Decisions regarding the assignment of assessment tasks to specific abilities, although made on the basis of expert judgement, were frequently not clear-cut. For example, a task called Reaction Time (Taskmaster battery) includes both simple ("Reaction Time") and choice ("Response Orientation") reaction time tasks. Of course, this task has been categorized accordingly. Further, although the MTPB's Code Lock Solving task imparts information by way of colored lights, use of "Visual Color Discrimination" abilities was considered incidental to performance on this task (i.e., the task is not designed to assess these abilities) and so Code Lock Solving is not included in the "Visual Color Discrimination" entry. Similarly, although every auditory task might, of necessity, require "General Hearing" ability, and every task requiring a keyboard input might require "Finger Dexterity", such categorizations were considered trivial and inappropriate unless the ability was a significant focus of a particular task.

It is important to note that, due to the relative numbers of each, the set of task batteries included here (ten batteries, one hundred twenty-three tasks) is substantially more representative of the population of such batteries than is the set of included models (seven) representative of the considerable number of human performance models (see, e.g., Pew, Baron, Feehrer, & Miller, 1977). The current effort is seen as the development of a new approach and should be regarded as an initial activity in a long-range, comprehensive research program.

II. Directory

This *Directory* is in five parts.

- **Section II A, Index of Abbreviations**, details the abbreviations/acronyms used in the remaining sections.

- **Section II B**, the **Ability Catalog** , is considered the focal point of the present effort. In it are listed the Fleishman & Quaintance human abilities and their corresponding descriptions and examples (1984, Appendices B, C). For each ability are listed the battery(ies) and specific task(s) requiring that ability and/or the performance "model(s)" concerned with or incorporating that ability.

- **Section II C** provides details of the **Computer-based Performance Assessment Batteries**. Note that to assure the accurate representation of each battery, we have, to the greatest extent possible, incorporated the original authors' exact text in our descriptions. For each task element detailed, we have indicated the ability from Section II B that is judged to be primarily associated with performance on that task. In some cases, a "construct" (UTC-PAB) or "psychological factor" (Taskmaster battery) has been provided by the original authors and has been included herein. Our purpose is not to provide a comprehensive specification for each task, but rather to offer sufficient detail to enable the reader to make broad comparisons between/among battery elements and to ascertain which original manuscripts to acquire.

- **Section II D** contains the summary descriptions of the **Human Performance Models / Theories** reviewed. Again, to assure the accurate presentation of this information, we have, to the greatest extent possible, incorporated the original authors' exact text in our descriptions. The Fleishman & Quaintance "abilities" deemed relevant for each model are listed following the summary description.

- **Section II E, Task Source References** lists those sources cited by the original authors as providing additional and/or historical data relevant to a particular task. In many cases (e.g., "Grammatical Reasoning" and the many variations of the *Sternberg* task), tasks of similar name have the same origin, even though each battery creator may not have provided such details.

II A. Index of Abbreviations

BATTERIES

APT. Automated Portable Test System

CTS. Criterion Task Set

IPPB. Information Processing Performance Battery (Wickens, et al., 1985)

MTPB. Multiple-Task Performance Battery

PORTA-BAT. Basic Attributes Tests-Version 4

NAVAL CCT. Naval Biodynamics Laboratory- Computerized Cognitive Testing battery

NES. Computer-Based Neurobehavioral Evaluation System

TASKMASTER. Taskmaster System / NIOSH Perfromance Battery

UTC-PAB. Unified Tri-Services Cognitive Performance Assessment Battery

WRAIR-PAB. Walter Reed Army Institute for Research Performance Assessment Battery

MODELS

BRAUNE. Braune & Foshay, 1983

CHU. Chu & Rouse, 1979

LEVISON. Levison, 1982

MURALIDHARAN. Muralidharan, et al., 1979

SANDERS. Sanders, 1983

WHERRY. Wherry & Curran, 1966

WICKENS. Wickens,1984

II B. ABILITY CATALOG

Arm-Hand Steadiness

The ability to keep the arm and hand steady (Examples: Thread a needle; light a cigarette).

BATTERY/TASK(S)	MODEL(S)
TASKMASTER - Hand Steadiness	none located to date

Auditory Attention

The ability to focus on a single source of auditory information in the presence of other distracting and irrelevant auditory stimuli (Example: Receive Morse code in a noisy radio room).

BATTERY/TASK(S)	MODEL(S)
IPPB - Dichotic Listening **UTC-PAB** - Dichotic Listening	Wickens

Category Flexibility

The ability to produce many rules so that each rule tells how to group a set of items in a different way. Each different group must contain at least two items from the original set (Examples: Sort nails on the basis of length; select fuses for projectiles).

BATTERY/TASK(S)	MODEL(S)
none located to date	Braune

Control Precision

The ability to move controls of a machine or vehicle quickly and repeatedly to exact positions. (Examples: Manipulate winch, crane, or "mule" (tow truck) controls).

BATTERY/TASK(S)	MODEL(S)
NAVAL CCT - Maze Task **NES** - Hand-Eye Coordination Test	Muralidharan Sanders Levison Wickens

Control Precision
(cont.)

PORTA-BAT
- Psychomotor Device Tests

Depth Perception

The ability to distinguish which of several objects is more distant or nearer the observer, or to judge the distance of an object from the observer (Examples: Operate a crane; fire a line-throwing gun; estimate range of targets; judge distance of other vessels).

BATTERY/TASK(S)	MODEL(S)
none located to date	none located to date

Deductive Reasoning

The ability to apply general rules to specific problems to come up with logical answers and decide if an answer makes sense (Examples: Design an aircraft wing using the principles of aerodynamics; navigate by dead reckoning; compute ship speed and course).

BATTERY/TASK(S)	MODEL(S)
CTS - Grammatical Reasoning **NAVAL CCT** - Code Substitution - Visual and Auditory Grammatical Reasoning **TASKMASTER** - Grammatical Reasoning - Grammatical Reasoning with Reaction Time **UTC-PAB** - Grammatical Reasoning (Symbolic) - Grammatical Reasoning (Traditional) **WRAIR-PAB** - Encoding/Decoding - Logical Reasoning	Braune Chu Muralidharan Wherry

Dynamic Flexibility

The ability to bend, stretch, twist, or reach out quickly and repeatedly with the body, arms, or legs (Examples: Swim; pull in a rope; climb a ladder). May be tested with a *repeated floor touch test.*

BATTERY/TASK(S)	MODEL(S)
none located to date	none located to date

Dynamic Strength

The ability to repeatedly or continuously exert force over a long period. This includes the ability to support, hold up, or move one's own body weight (Examples: Haul in a line; load ammunition). May be tested with *pull-ups and push-ups.*

BATTERY/TASK(S)	MODEL(S)
none located to date	none located to date

Explosive Strength

The ability to use short bursts of force to propel an object or one's own weight (Examples: Throw a heavy line; hook an aircraft to a catapult; run with a fire hose). May be tested with *sprint running.*

BATTERY/TASK(S)	MODEL(S)
none located to date	none located to date

Extent Flexibility

The ability to bend, stretch, twist, or reach out with the body, arms, or legs (Examples: Pick up a wrench; perform aircraft maintenance on hard to reach equipment). May be tested with *twist and touch exercises.*

BATTERY/TASK(S)	MODEL(S)
none located to date	none located to date

Far Vision

The capacity to see distant environmental surroundings (Examples: Receive semaphore; identify bouys; detect differences in ships on the horizon; perform lookout duties).

BATTERY/TASK(S)	MODEL(S)
none located to date	none located to date

Finger Dexterity

The ability to make skillful, coordinated movements with the fingers to grasp, place, or move small objects (Example: Tie/untie seamanship knots; align/adjust electronic equipment; arm or make connections on missiles).

BATTERY/TASK(S)	MODEL(S)
CTS	none located to date
- Interval Production	
- Unstable Tracking	
IPPB	
- Critical Instability Tracking	
- Second Order Tracking	
NAVAL CCT	
- Maze Task	
NES	
- Hand-Eye Coordination	
PORTA-BAT	
- Psychomotor Device Tests	
- Time Sharing	
TASKMASTER	
- Response Alternation	
UTC-PAB	
- Interval Production	
- Unstable Tracking	

Flexibility of Closure

The ability to identify or detect a known pattern (like a figure, word, or object) that is hidden in other material (Example: Find a particular size nut or bolt from an assortment of nuts and bolts).

BATTERY/TASK(S)	MODEL(S)
CTS	Sanders
- Memory Search	
IPPB	
- Embedded Figures	
PORTA-BAT	
- Embedded Figures	
UTC-PAB	
- Visual Scanning	
WRAIR-PAB	
- Six-Letter Search	
- Two-Letter Search	
- Visual Scanning	

Fluency of Ideas

The ability to produce a number of ideas about a given topic (Example: Brainstorm to generate possible solutions to a problem).

BATTERY/TASK(S)	MODEL(S)
none located to date	none located to date

General Hearing

The ability to detect and discriminate among sounds that vary in pitch and/or loudness (Example: Distinguish between/among general, collision, chemical, and crash alarms).

BATTERY/TASK(S)	MODEL(S)
TASKMASTER - Noise Fusion	none located to date

Glare Sensitivity

The ability to see objects in the presence of glare or bright ambient lighting (Examples: Detect submarine periscopes or torpedo wakes).

BATTERY/TASK(S)	MODEL(S)
none located to date	Levison

Gross Body Coordination

The ability to coordinate the movement of the arms, legs and torso together in activities where the whole body is in motion (Examples: Climb a ladder; man a fire hose). May be tested by *jump-roping.*

BATTERY/TASK(S)	MODEL(S)
none located to date	none located to date

Gross Body Equilibrium

The ability to keep or regain one's body balance or to stay upright when in an unstable position (Examples: Work while standing on a ladder; walk with slippery footing conditions; stand on-board ship in heavy seas).

BATTERY/TASK(S)	MODEL(S)
none located to date	none located to date

Inductive Reasoning

The ability to combine separate pieces of information, or specific answers to problems, to form general rules or conclusions. This involves the ability to think of possible reasons why things go together (Examples: Interpret a weather chart; interpret sonar information).

BATTERY/TASK(S)	MODEL(S)
CTS	Braune
- Linguistic Processing	Chu
MTPB	Muralidharan
- Code Lock Solving	Wherry
NAVAL CCT	
- Logic Task	
UTC-PAB	
- Linguistic Processing	
- Linguistic Processing-Choice Reaction Time Combination	

Information Ordering

The ability to follow correctly a rule or set of rules to arrange things or actions in a certain order. The rule or set of rules used must be given. The things or actions to be put in order can include numbers, letters, words, pictures, procedures, sentences, and mathematical or logical operations (Example: Establish fault detection procedures).

BATTERY/TASK(S)	MODEL(S)
none located to date	Chu Muralidharan

Manual Dexterity

The ability to quickly make skillful coordinated movements of one hand, a hand and an arm, or two hands to grasp, place, move, or assemble objects such as tools or blocks (Examples: Pack items in crates; make equipment repairs; arm weapons).

BATTERY/TASK(S)	MODEL(S)
NAVAL CCT - Spoke Task	none located to date

Mathematical Reasoning

The ability to understand and organize a problem and then select a mathematical method or formula to solve the problem (Examples: Determine how to calculate a trajectory; determine compass course).

BATTERY/TASK(S)	MODEL(S)
none located to date	none located to date

Memorization

The ability to remember information, such as words, numbers, pictures and procedures. Pieces of information can be remembered by themselves or with other pieces of information (Example: Memorize the pledge of allegiance to the flag).

BATTERY/TASK(S)	MODEL(S)
CTS	Wickens
- Continuous Recall	
- Mathematical Processing	
- Memory Search	
IPPB	
- Absolute Difference Calculation	
- Auditory-Verbal Sternberg	
- Visual-Spatial Sternberg	
- Visual-Verbal Sternberg	
MTPB	
- Code Lock Solving	
- Target Identification	
NAVAL CCT	
- Auditory Digit Span	
- Logic Task	
- Pattern Comparison	
- Sternberg Memory Scanning	
- Visual or Auditory Serial Addition	
NES	
- Digit Span	
- Paired Associate Learning	
- Pattern Memory	
- Memory Scanning	
PORTA-BAT	
- Immediate/Delayed Memory	
- Item Recognition	
TASKMASTER	
- Arithmetic Speed	
- Free Recall of Word List	
- Grammatical Reasoning	

Memorization
(cont.)

UTC-PAB
- Continuous Recall
- Mathematical Processing
- Matrix Rotation
- Memory Search
- Short-Term Memory

WRAIR-PAB
- Digit Recall
- Pattern Recognition I
- Pattern Recognition II
- Serial Add/Subtract

Multilimb Coordination

The ability to coordinate movements of two or more limbs such as in moving equipment controls (Examples: Operate a forklift, winch, crane, "mule", etc.).

BATTERY/TASK(S)	MODEL(S)
PORTA-BAT - Psychomotor Device Tests	none located to date

Near Vision

The capacity to see close surroundings (Examples: Read fine print; identify cable/wire markings).

BATTERY/TASK(S)	MODEL(S)
none located to date	Levison

Night Vision

The ability to see under low light conditions (Example: Detect phosphorescent wakes from small craft).

BATTERY/TASK(S)	MODEL(S)
none located to date	Levison

Number Facility

This involves the degree to which adding, subtracting, multiplying, and dividing can be done quickly and correctly. These can be steps in other operations like finding percentages

Number Facility
(cont.)

and taking square roots (Examples: Inventory parts or supplies; calculate ship closing rates during manuevering).

BATTERY/TASK(S)	MODEL(S)
CTS - Mathematical Processing **IPPB** - Absolute Difference Calculation **MTPB** - Arithmetic Computations **NAVAL CCT** - Math Test - Visual or Auditory Serial Addition **TASKMASTER** - Arithmetic Speed **UTC-PAB** - Mathematical Processing - Two Column Addition **WRAIR-PAB** - Serial Add/Subtract - Two Column Addition	none located to date

Oral Comprehension

The ability to understand spoken words and sentences (Example: Understand verbal orders or instructions).

BATTERY/TASK(S)	MODEL(S)
none located to date	none located to date

Oral Expression

The ability to use words and sentences in speaking so others will understand (Examples: Give instructions; relay information).

BATTERY/TASK(S)	MODEL(S)
none located to date	none located to date

Originality

The ability to generate novel ideas ragarding a particular issue or situation and/or to invent creative solutions to problems (Example: Use a credit card to open a locked door).

BATTERY/TASK(S)	MODEL(S)
none located to date	none located to date

Perceptual Speed

This involves the degree to which one can compare letters, numbers, objects, pictures, or patterns, quickly and accurately. The things to be compared may be presented at the same time or one after the other. This ability also includes comparing a presented object with a remembered object (Examples: Inspect assembled electrical components for defects; compare readings from a bank of dials/gauges; identify radar returns on a scope).

BATTERY/TASK(S)	MODEL(S)
CTS - Continuous Recall - Linguistic Processing - Memory Search - Spatial Processing **IPPB** - Auditory-Verbal Sternberg - Visual-Spatial Sternberg - Visual-Verbal Sternberg **MTPB** - Target Identification **NAVAL CCT** - Code Substitution - Pattern Comparison - Sternberg Memory Scanning - Visual or Auditory Recognition **NES** - Continuous Performance - Memory Scanning - Pattern Memory - Pattern Recognition - Symbol-Digit Substitution - Visual Retention **PORTA-BAT** - Dot Estimation - Encoding Speed - Item Recognition - Immediate/Delayed Memory - Mental Rotation - Perceptual Speed	Braune Sanders

Perceptual Speed
(cont.)

UTC-PAB
- Alpha-Numeric Visual Vigilance
- Code Substitutions
- Continuous Recall
- Linguistic Processing
- Linguistic Processing-Choice Reaction Time
- Matrix Rotation
- Memory Search Task
- Pattern Comparison (Simultaneous)
- Pattern Comparison (Successive)
- Short-Term Memory
- Spatial Processing
- Continuous Recall

WRAIR-PAB
- Digit Recall
- Pattern Recognition I
- Pattern Recognition II
- Six Letter Search
- Two Letter Search

Peripheral Vision

The ability to perceive objects or movement in the edge of the visual field (Example: Monitor the instrument panel of a jet aircraft).

BATTERY/TASK(S)	MODEL(S)
CTS - Probability Monitoring **MTPB** - Probability Monitoring **UTC-PAB** - Visual Probability Monitoring	none located to date

Problem Sensitivity

The ability to tell when something is wrong or is likely to go wrong. It includes being able to identify the whole problem as well as the elements of the problem (Examples: Recognize an illness at an early stage of a disease when there are only a few symptoms; detect crew morale problems).

Problem Sensitivity
(cont.)

BATTERY/TASK(S)	MODEL(S)
none located to date	Braune
	Chu
	Muralidharan
	Wherry

Rate Control

The ability to adjust an equipment control in response to changes in the speed and/or direction of a continuously moving object or scene. This ability does not extend to situations in which both the speed and direction of the object are perfectly predictable (Example: Maintain a gun sight on a moving target).

BATTERY/TASK(S)	MODEL(S)
CTS	Wickens
- Unstable Tracking	
IPPB	
- Critical Instability Tracking	
- Second Order Tracking	
PORTA-BAT	
- Time Sharing	
UTC-PAB	
- Unstable Tracking Task	

Reaction Time

The ability to give one fast response to one signal (sound, light, picture) when it appears. This ability involves the speed with which the movement can be started with the hand, foot, or other parts of the body (Example: Duck to miss being hit by an object).

BATTERY/TASK(S)	MODEL(S)
NES	Chu
- Continuous Performance Test	Muralidharan
- Simple Reaction Time	Sanders
TASKMASTER	Wherry
- Grammatical Reasoning with Reaction Time	Wickens
- Reaction Time	

Response Orientation

The ability to choose between two or more movements quickly and accurately when two or more different signals (lights, sounds, pictures) are given. The ability is concerned with the speed with which the correct response can be started by the hand, foot, or other parts of the body (Example: Operate a busy telephone switchboard).

BATTERY/TASK(S)

MTPB
- Blinking Lights Monitoring
- Warning Lights Monitoring

NAVAL CCT
- Choice Reaction Time
- Manikin
- Stroop-like Color Naming

PORTA-BAT
- Decision-Making Speed
- Perceptual Speed

TASKMASTER
- Reaction Time

UTC-PAB
- Alpha-Numeric Visual Vigilance
- Four-Choice Serial Reaction Time
- Linguistic Processing-Choice Reaction Time
- Manikin Test
- Sternberg-Tracking
- Stroop Test

WRAIR-PAB
- Four-Choice Serial Reaction Time

MODEL(S)

Chu
Muralidharan
Sanders
Wherry
Wickens

Selective Attention

The ability to concentrate on a task, including boring tasks (Examples: Carry on a conversation in a noisy room; watch a radar screen).

BATTERY/TASK(S)

IPPB
- Dichotic Listening

NAVAL CCT
- Stroop-like Color Naming

TASKMASTER
- Zip Code Typing

UTC-PAB
- Manikin Test
- Stroop Test

MODEL(S)

Braune
Chu
Sanders
Wickens

Sound Localization

The ability to identify the direction from which an auditory stimulus originates relative to the observer (Examples: Locate someone calling your name or the source of a sonalert or other audible alarm signal).

BATTERY/TASK(S)	MODEL(S)
none located to date	none located to date

Spatial Orientation

The ability to determine your position in relation to some object, or to ascertain the object's position in relation to you (Examples: Locate your position on a chart; manuever your ship in relation to others; position aircraft on a flight deck).

BATTERY/TASK(S)	MODEL(S)
IPPB - Maze Tracing	Wickens

Speech Clarity

The ability to communicate orally in an understandable fashion (Examples: Calling out numbers to someone; speak over a megaphone or telephone).

BATTERY/TASK(S)	MODEL(S)
none located to date	none located to date

Speech Hearing

The ability to understand the speech of another person (Example: Understanding verbal instructions).

BATTERY/TASK(S)	MODEL(S)
NAVAL CCT - Auditory Digit Span - (Visual and) Auditory Grammatical Reasoning - (Visual or) Auditory Serial Addition	none located to date

Speed of Closure

This involves the degree to which different pieces of information can be combined and organized into one meaningful pattern quickly. The material may be visual or auditory (Example: Interpret patterns on a weather chart).

BATTERY/TASK(S)	MODEL(S)
MTPB - Code Lock Solving	Braune

Speed of Limb Movement

This involves the speed with which a single movement of the arms or legs can be made irrespective of accuracy or coordination of movement (Examples: Swat at a fly; play out line replenishment).

BATTERY/TASK(S)	MODEL(S)
none located to date	Sanders

Stamina

The ability to withstand considerable physical exertion without becoming winded or fatigued (Examples: Fight a fire; load ammunition). May be tested with a *mile run* test.

BATTERY/TASK(S)	MODEL(S)
none located to date	none located to date

Static Strength

The ability to lift, push, pull, or carry objects. It is the maximum force one can exert for a brief period (Examples: Lift ammunition; man a high pressure hoze nozzle). May be tested with a *weight lift* test.

BATTERY/TASK(S)	MODEL(S)
none located to date	none located to date

Time Sharing

The ability to shift back and forth between two or more sources of information (Example: Simultaneously monitoring information from several teletypes or display screens).

Time Sharing
(cont.)

BATTERY/TASK(S)	MODEL(S)
CTS	Levison
- Probability Monitoring	Wickens
IPPB	
- Second Order Tracking	
MTPB	
- Probability Monitoring	
PORTA-BAT	
- Psychomotor Device Tests	
- Time Sharing	
UTC-PAB	
- Linguistic Processing-Choice Reaction Time	
- Sternberg-Tracking	
- Visual Probability Monitoring	
TASKMASTER	
- Grammatical Reasoning with Reaction Time	

Trunk Strength

The ability of one's stomach and lower back muscles to resist fatigue as they repeatedly or continuously support part of the body (Example: Lift heavy objects from the ground). May be tested by *sit-up and leg-lift* tests.

BATTERY/TASK(S)	MODEL(S)
none located to date	none located to date

Visual Color Discrimination

The capacity to match or detect differences between colors and/or levels of color saturation and brightness (Examples: Match grains from samples of wood; discriminate landing lights; detect types of navigational running lights on a vessel).

BATTERY/TASK(S)	MODEL(S)
NAVAL CCT	none located to date
- Manikin	
- Stroop-like Color Naming	
UTC-PAB	
- Manikin	
- Stroop Test	

Visualization

The ability to imagine how something will look when it is moved around or when its parts are moved or rearranged. One has to predict how an object, set of objects, or pattern will appear after the changes are carried out (Examples: Know how to cut and fold a piece of paper to make a cube; position aircraft on a flight deck; read another ship's running lights as it manuevers in relation to own ship).

BATTERY/TASK(S)	MODEL(S)
CTS	none located to date
- Spatial Processing	
MTPB	
- Target Identification	
NAVAL CCT	
- Manikin Test	
PORTA-BAT	
- Mental Rotation	
UTC-PAB	
- Manikin Test	
- Matrix Rotation	
- Spatial Processing	

Wrist-Finger Speed

The ability to make fast, simple, repeated movements of the fingers, hands, and wrists without regard for accuracy or eye-hand coordination (Examples: Transmit flashing light messages; screw nuts onto studs).

BATTERY/TASK(S)	MODEL(S)
APTS	none located to date
- Tapping	

Written Comprehension

The ability to understand written sentences and paragraphs (Examples: Understand written orders, instructions, or message traffic).

BATTERY/TASK(S)	MODEL(S)
CTS	none located to date
- Grammatical Reasoning	
NAVAL CCT	
- Visual and Auditory Grammatical Reasoning	
NES	
- Vocabulary	
PORTA-BAT	
- Self-Crediting Word Knowledge	

Written Comprehension
(cont.)

TASKMASTER
- Grammatical Reasoning
- Grammatical Reasoning with Reaction Time

UTC-PAB
- Grammatical Reasoning (Traditional)

WRAIR-PAB
- Logical Reasoning

Written Expression

The ability to use words and sentences so others can comprehend (Example: Write a message).

BATTERY/TASK(S)	MODEL(S)
none located to date	none located to date

II C. Computer-Based Performance Assessment Batteries

Note: To assure the accurate representation of each battery, these descriptions are, to a great extent, presented in the words of the original author(s).

Automated Portable Test System (APTS)

Bittner, A.C., Smith, M.G., Kennedy, R.S., Staley, C.F. & Harbeson, M.M. (1985). Automated Portable Test (APT) System: Overview and prospects. Behavior Research Methods, Instruments, & Computers, 17(2), 217-221.

Development of the APTS is based upon the concepts and empirical findings of the Performance Evaluation Tests for Environmental Research (PETER) Program (e.g., Harbeson, Bittner, Kennedy, Carter, & Krause, 1983; see also Irons & Rose, 1985 and the NAVAL CCT description in this *Directory*). The PETER Program is a compilation of tasks that meet certain psychometric properties--test stability, reliability, and suitability for use in repeated mesure designs,and a number of these tasks have been implemented in APTS. The APTS has been developed as a tool for the assessment of human performance and subjective status. At present, it is being used in investigations of the effects of flight-simulator exposure on pilots, hypoxia effects on soldiers and a variety of university studies. The APTS is a notebook-sized microcomputer system that is said to be portable, rugged, user friendly, utilizes an independent power source and provides storage for data. The producers contend that APTS is particularly useful for environmental research where time, space and accessibility make other test methods difficult. Future plans include adaptation of the UTC-PAB on APTS hardware/software.

The APTS is produced and sold by ESSEX Corporation, Orlando, FL .

Hardware/Software

The hardware system is built around a notebook-sized eight bit personal computer, the NEC PC 8201A. There is a 32K internal ROM containing, in addition to TELCOM and TEXT EDITOR, a version of Microsoft BASIC.

ESSEX Corporation provides software for the Automated Portable Test System in the form of tests and questionnaires. An additional PC-8206A 32Kb RAM cartridge must be purchased as the medium for shipment and customer backup. Generally, up to five (5) tests or two (2) questionnaires may be placed on one cartridge. Scores available generally include Hits, Errors, and Latencies. Where appropriate, calculated scores (e.g., rights minus wrongs, average velocity, log latency) are also used. The software is warranted for one year.

The following table abstracts the technical features of the microcomputer:

FEATURES	SPECIFICATIONS
Size	30 x 22 x 6 cm (11 x 8.25 x 2.5 in.)
Weight	1.7 kg (3.8 lb)
CPU	80C85 (CMOS version of 8085) with 2.4 MHz clock
ROM	32K (standard) 128K (optional)
RAM	16K (standard) 96K (optional)
Keyboard	67 standard keys: 5 function, 4 cursor directional, and 58 additional
Display	19 x 5 cm (7.5 x 2 in) with reverse video option (may be configured as either a 240 x 64 element matrix or a 40 character x 8 line display)

Interfaces	1 Parallel (Centronics compatible) and 3 serial (RS-232C and 6- and 8-pin berg jacks)
Power Supply Options	4 AA nonrechargeable batteries, or rechargeable nickle-cadmium pack, or ac adapter 50/60 Hz @ 120 V ac, or external battery systems

Tasks

Following is a list of tasks that have been available for use with the APTS. Purchasers may select from this list those tasks that best suit their needs. No task descriptions were available from Essex at the time of this report but, in general, they can be expected to be similar to those of like name in other batteries detailed in this *Directory.*

1. **Code Substitution**
2. **Grammatical Reasoning**
3. **Manikin**
4. **Moving Landolt C**
5. **Non-Preferred Hand Tapping**
6. **Pattern Recognition**
7. **Preferred Hand Tapping**
8. **Reaction Time**
9. **Sternberg**
10. **Two-Hand Tapping**

Criterion Task Set (CTS)

Shingledecker, C.A. (1984). A task battery for applied human performance assessment research. (Technical Report AFAMRL-TR-84). Dayton, OH: US Air Force Aerospace Medical Research Laboratory.

The Criterion Task Set (CTS) is a battery of tasks which has been developed to provide an instrument for human performance assessment that is both practical and firmly based in current theoretical models of perceptual-motor and cognitive behavior. The component tasks place selective demands on the functional information processing resources of the human operator. The CTS' primary framework or model is derived from multiple resource and processing stage theories.

The theoretical basis and standardized features of the CTS are said to make it potentially applicable to a number of research problems in the areas of human performance assessment and human factors. One of the problems for which the CTS was originally designed was the comparative evaluation of measures of mental workload. In this application, the individual components of the CTS are being used as primary loading tasks to assess the reliability, sensitivity and intrusiveness of a number of proposed behavioral, subjective and physiological indices of workload. A second broad area of investigation to which the CTS can be applied as a standardized test instrument is the assessment of human performance capabilities. When used for this purpose, the tasks comprising the CTS may be employed in a diagnostic fashion to measure and predict the effects of extreme environments and biochemically active agents on human performance.

Three significantly different demand (difficulty) levels have been established for each CTS task except Interval Production. Additional tasks are currently being developed for later inclusion into the CTS, and plans to adapt this battery for IBM-compatible machines are under consideration.

Hardware

The CTS is implemented on a commercially available microcomputer system with a minimum of additional custom-built hardware. An equipment listing includes the following: Commodore 64 microcomputer, Commodore 1541 disk drive, Commodore C1526 printer (or MPS-801), Monochrome experimenter's monitor (Panasonic WB5200 or equivalent with 75 ohm loop-through and female BNC video input connector), Commodore 1702 color subject's monitor (substitute not recommended), experimenter's video monitor switch and cables (custom), four button response keypad and cable (custom), tapping key and cable (custom), and rotary tracking control and cable (custom).

Software

The software for the CTS is written primarily in BASIC to run on the Commodore 64 computer. The majority of the programs are compiled to improve execution speed and efficiency. The CTS software is structured to minimize experimenter familiarization and training requirements. Standardized, self-explanatory menus are used for all tasks to simplify trial preparation and data handling activities. Once task software is loaded into the computer, initial menus permit the experimenter to select training or test conditions and specific loading levels on the task.

Task Descriptions

Continuous Recall - This task is a standardized loading task designed to place variable demands upon processing resources associated with encoding and storage in working memory. The task requires an operator to utilize both immediate and short term memory of numbers under continously changing storage states. The memory test consists of a random series of visual presentations of numbers which the operator must encode in a sequential fashion. As each number in the series is presented for encoding, a probe number is presented simultaneously. The operator must compare this probe number to a previously presented item that occurred at a prespecified number of positions back in the series. The operator must decide if the items are the same as/or different from the probe number. Task difficulty is manipulated by varying the number of digits in each item and the length of series which must be maintained in memory in order to respond to recall probes. The task is experimenter (computer) paced. (PERCEPTUAL SPEED, MEMORIZATION)

Grammatical Reasoning - Variable processing demands on resources required for logical thought are imposed by this task. Stimuli are sentences of varying syntactical structure which refer to and are presented simultaneously with a set of symbols. Subjects must analyze the sentences to ascertain whether they correctly describe the relationship between/among the displayed symbols. Task complexity is varied by the amount and difficulty of grammatical analysis required, including, for example presentation of one versus two sentence stimuli, use of active versus passive wordings, and/or positive versus negative sentence structure. (DEDUCTIVE REASONING, WRITTEN COMPREHENSION)

Interval Production - The operator is required to generate a series of equal time intervals by producing a consistent rate of finger tapping within the range of one to three taps per second. The standard deviation of interval durations and an "IPT variability" score which corrects for the partial dependence of error magnitude on interval duration, are the dependent measures employed. (FINGER DEXTERITY)

Linguistic Processing - This task places variable demands upon mental resources associated with the manipulation and comparison of linguistic information. The task requires classification of letter and word pairs as "same" or "different" on the basis of three stimulus dimensions, physical, categorical and antonym ranging from low to high task demand, respectively. Task difficulty is determined by the dimension along which stimuli are compared. Letter or word pairs are presented on a CRT. Subjects respond positively if the items match on the dimension in question or negatively otherwise. Reaction time and subjective ratings are evaluated. (PERCEPTUAL SPEED, INDUCTIVE REASONING)

Mathematical Processing - This task places variable demands upon information processing resources associated with the manipulation and comparison of numeric stimuli. The task requires the subject to perform one or more simple arithmetic operations on visually presented single digit numbers to determine whether the correct answer is greater or less than a prespecified value (5). Task complexity is determined by the number and combination of operations in the problems. Mean reaction times, percentage correct, and subjective ratings are collected. Tasks are subject paced with experimenter-set time constraints. (NUMBER FACILITY, MEMORIZATION)

Memory Search - This task is designed to place variable demands on human information processing resources dedicated to short-term memory retrieval functions. A small set of items (the "memory set") is first presented to the subject for memorization. A series of test items is then presented to the subject one at a time, and the subject must respond positively if the test item was contained in the memory set, or negatively if not. Reaction time is measured from the onset of the test item to the response. The task is composed of three fixed-demand levels produced by variations in the number of items to be memorized.

Memory Search (cont.)
This task is subject paced within experimenter-set time constraints. Stimulus items in the CTS memory search task are visually presented alphabetic characters. Due to the acoustic confusability of certain letters, only seventeen of the twenty-six letters of the alphabet are used in the task (ABCEFGHIJLOQRSXYZ). Memory set items are randomly selected from the letter population, and the remaining items are used in the negative set. A new memory set is selected at the beginning of each three minute test period. Test items are also randomly generated with the restriction that positive and negative set items are drawn with equal probability. Responses are entered on appropriately labeled keys. (MEMORIZATION, PERCEPTUAL SPEED)

Probability Monitoring - (Note: this task has been recently revised. Details of this new version were not available for inclusion in the *Directory*). This task places variable demands on the visual perceptual information processing resources of the human operator. The task includes three fixed loading levels produced by variations in the number of signal sources (dials) and in the discriminability of signals. Subjects monitor either one, three, or four computer generated displays, having the appearance of electro-mechanical dials. Each display consists of a row of six vertical hashmarks with the seventh mark offset above the others to indicate the center of the dial. Subjects are required to detect biased pointer movements. There are signaled, unsignaled and loaded conditions. Under normal (nonsignal) conditions a pointer located below the hashmarks moves from one position to another in a random fashion to simulate the pointer fluctuations on an actual dial. At unpredictable intervals, the pointer on a display begins to move nonrandomly, staying predominantly to the left or right half of the dial. These biases in pointer movement are the targets or "signals" to which subjects are instructed to respond. By pressing the appropriate response key, biased dials are returned to the nonsignal (random pointer movement) state. (TIME SHARING, RESPONSE ORIENTATION, some performance strategies may utilize PERIPHERAL VISION)

Spatial Processing - This task is designed to place variable demands upon information processing resources required for the manipulation and comparison of spatial information. This task requires the subject to view a series of histograms presented one at a time. The subject must determine whether the second histogram in each set of two (the "comparison" item) is identical to the first (the "target" item) and respond either positively or negatively. Target and comparison histograms are marked with the numbers 1 and 2, respectively, so that subjects can keep track. Task demands are manipulated by varying the number of bars in the histograms and the spatial orientation of the comparison histogram. Mean reaction times and subjective ratings are collected. The task is experimenter paced within the range 1.5 to 3.5 seconds increasing with task difficulty. (PERCEPTUAL SPEED, VISUALIZATION)

Unstable Tracking - The execution of rapid and accurate manual responses are required by this task, which has three possible levels of task demand. As a cursor moves vertically from the center of the CRT screen, the subject attempts to re-center it through rotary movements of a control knob. These responses, in turn, introduce error which is magnified by the system so that it becomes increasingly necessary for subjects to respond to the velocity of the cursor movement as well as to its position relative to the center. (RATE CONTROL, FINGER DEXTERITY)

Information Processing Performance Battery (IPPB)

Wickens, C. D., Braune, R., Stokes, A. & Strayer, D. (1985). Individual Differences and Age-Related Changes: Refinement and Elaboration of an Information Processing Performance Battery with Aviation Relevant Task Structures. (NAMRL-85-1). Pensacola, FL: U.S. Naval Aerospace Medical Research Laboratory.

This test battery examines the general effects of aging on human information processing skills assumed to be relevant to, although not exclusively directed towards, aviation. It is said to be a general demonstration of how performance analysis, controlled experimental manipulation, and factor analysis can reveal the different dimensions of information processing and can demonstrate how these dimensions are influenced by a variety of factors. The combined techniques employed are reported to be equally applicable in examining the effects of chronological aging, the effects of stress level, the effects of different drugs or the effects of sleep deprivation.

Hardware/Software
Information not available in documents obtained to date.

Task Descriptions

Absolute Difference Calculation - The subject is presented with a series of digits through headphones. The subject's task is to calculate the difference between the last digit presented and the previous one, and to press the appropriate button on a keyboard. In the sequence 4,1,5,3, for example, the correct responses would be 3,4, and 2. (MEMORIZATION, NUMBER FACILITY)

Auditory-Verbal Sternberg (AV) - This task is identical to the above task, except that the stimuli are presented auditorily through headphones. (PERCEPTUAL SPEED, MEMORIZATION)

Critical Instability Tracking - In this task, the subject moves a spring-loaded joystick in a left-right direction with the right hand in order to stabilize an unstable positive feedback element. The subjective impression of this task is that of balancing a dowell rod on the end of one's finger, while the rod progressively shortens in length. (RATE CONTROL, FINGER DEXTERITY)

Dichotic Listening - The subject is simultaneously presented with a series of word and digit pairs to both ears. During Phase I (focused attention), the subject reports only the digits presented to one ear and ignores those presented to the other ear. During Phase II (attention switching) a cue is presented to switch the relevant ear, and the subject is judged on the accuracy of reporting the digits on the now-relevant channel. (AUDITORY ATTENTION, SELECTIVE ATTENTION)

Embedded Figures - Subjects view a target pattern followed by a series of stimuli. For each stimulus, the subject decides whether or not the target pattern was contained in the stimulus pattern and indicates his/her response with a yes-no button press. (FLEXIBILITY OF CLOSURE, MEMORIZATION)

Maze Tracing - The subject views a computerized maze and is required to decide as rapidly as possible whether or not there was an open path from start to finish and to so indicate by a Yes or No button press. (SPATIAL ORIENTATION)

Second-Order Tracking - The subject manipulates a spring-loaded joystick in the left-right direction with the right hand in order to minimize the error on a horizontal compensatory display. Control is exercised using second order (double integral or acceleration) dynamics. The subject attempts to track a band-limited disturbance input with an upper cutoff frequency of 0.32 Hz. This task may be presented concurrently with the Sternberg visual tasks in which case the Sternberg responses are made with the left hand. (TIME SHARING, CONTROL PRECISION, FINGER DEXTERITY)

Visual-Spatial Sternberg (VS) - This task is analagous to the (VV) task, except that the stimuli consist of line segments formed by connecting a pair of points in a two-by-three matrix. (PERCEPTUAL SPEED, MEMORIZATION, SPEECH HEARING)

Visual-Verbal Sternberg (VV) - Prior to each trial, the subject is presented with a memory set of two or three randomly chosen letters. Each letter is presented for three seconds for two cycles. Following this presentation, a series of probe letters is presented, fifty percent of which are drawn from the memory set. The subject uses a two button control switch to indicate if the probe was or was not a member of the memory set. (PERCEPTUAL SPEED, MEMORIZATION)

Multiple-Task Performance Battery (MTPB)

Morgan, Jr., B. B. & Alluisi, E. A. (1972). Synthetic work: Methodology for assessment of human performance, Perceptual and Motor Skills, 35, 835-845.

At present, this is not a microcomputer based battery, but efforts to transform it into such are currently in progress. The MTPB incorporates five individual-performance tasks and one group-performance task. The tasks are presented according to a repeated basic two hour schedule. With each cycle of the two hour performance period, a total of fourteen individual- and five group-performance measures are obtained for each of the subjects.

Typical MTPB Study

The typical MTPB study is conducted in four phases. Phase I consists of training for forty-eight hours in blocks of no less than four hours. Phase II (baseline phase) typically consists of two consecutive days of MTPB performance following a four hour on, four hour off, four hour on, and twelve hour off duty schedule. Phase III (experimental phase) the variable of manipulation is imposed; the number of hours and period involved varies as a function of the particular investigation. There is typically a rest and recovery period immediately following the experimental phase during which no MTPB data are collected. Following this rest and recovery period there is Phase IV, the post rest and recovery phase, during which two additional consecutive days of MTPB performance data are collected according to the 4-4-4-12 work rest schedule. On a few studies, a fifth phase has been required to provide data regarding an additional independent variable.

Task Descriptions

Arithmetic Computations - The display for this task is presented along the lower central portion of the panel and consists of three three-digit numbers arranged horizontally. The subject is required to add the first three-digit number to the second and then subtract from their sum the third three-digit number. Use of paper and pencil is not permitted. The subject records an answer by manipulating four decade thumb switches, and pressing a push button. A blue light indicates a correct answer. Problems are presented at a rate of three per minute for thirty minute intervals. Performance is scored in terms of percentage of problems attempted and the percentage of problems correctly answered. (NUMBER FACILITY)

Blinking Lights Monitoring - The subject is presented with two vertically arranged amber lights. Under normal conditions, the two lights flash alternately at an over-all blink rate of two flashes per second. The critical signal to be detected by the subject is an arrest of this alternating operation. Subjects are required to respond by pressing a button located directly below the pair of lights. If the subject fails to respond within two minutes he/she receives the maximum latency score. (RESPONSE ORIENTATION)

Code Lock Solving - This is a group performance task that requires a five man crew to discover the proper sequential order for depressing five push buttons, one for each member. Illumination of a red light indicates that a problem is present and unsolved. The amber light is presented when any one of the subjects depresses a button. The red light extinguishes when the first correct response is made. When an erroneous response occurs, the red light is presented and the programming apparatus automatically resets to the beginning of the sequence. When all five push buttons have been depressed in the correct order, a green light is presented. There is a thirty second interval and the subjects are required to re-solve the same problem. Then another thirty second interval occurs followed by a second original problem.

Code Lock Solving (cont.)
Performance measures include: time required for code-lock solutions, total number of responses made, total number of errors (program resettings), and the mean number of sequences solved per unit of time. (INDUCTIVE REASONING, SPEED OF CLOSURE, MEMORIZATION)

Probability Monitoring - Four semi-circular scales located along the upper portion of the experimental panel are used to display the probability monitoring task. The subject's task is to detect a bias (movement of the pointer in the center to either the right or the left) by pressing a button under the meter with the bias. Data recorded include number of biases presented, the number of bias signals correctly detected, the number of false alarms and the response time. (TIME SHARING, some performance strategies may utilize PERIPHERAL VISION)

Target Identification - In the center of the subject's panel, there is a six-by-six matrix of close-butted square lights. Metric histoforms are created by using lit and unlit lights. The subject is typically presented with a five second display of the target image followed by a five second off period. There is a two second display of a randomly positioned (rotated) choice image, a two second off period, and a two second display of a second choice image. The response period is fourteen seconds. Each subject is required to respond by pushing one of three buttons to indicate that the first, second, or neither choice was the same as the target original. A blue light indicates a correct response above the appropriate button. (PERCEPTUAL SPEED, MEMORIZATION, VISUALIZATION)

Warning Lights Monitoring - The subject is presented with a pair of warning lights, one red and one green. The normal state is depicted by green-on, red-off. The subject is required to detect any change in state, and to respond by turning the green light on if it goes off, or turning the red light off if it comes on. The subject responds by pressing a push button located immediately below the light in question. Latency data are transformed to normalized speed scores. If the subject does not respond within two minutes, he/she will receive the maximum latency score. (RESPONSE ORIENTATION)

Naval Biodynamics Laboratory Computerized Cognitive Testing (Naval CCT)

Irons, R. & Rose, P. (1985). Naval biodynamics laboratory computerized cognitive testing. Neurobehavioral Toxicology and Teratology, 7, 395-397.

The Naval Biodynamics Laboratory has developed a network system of microcomputers to test subjects within a laboratory setting and within unusual environments (e.g., impact acceleration, vibration endurance testing, ship motion simulation). A NESTAR network configuration permits the sharing of test programs and data bases between any of the test stations. This allows testing to be conducted concurrently between test sites in a time-sharing mode.

A description of the task selection process for this project and of several studies carried out using these tests (including paper and pencil versions) is described by Harbeson, Bittner, Kennedy, Carter, & Krause (1983).

Hardware

The required hardware includes an Apple II (48K RAM) or Apple IIe; Mountain Hardware Supertalker; Mountain Hardware Clock/Calendar Card; LPS II Light Pen by Gibson Laboratories; two 5 1/4" disk drives; an Apple II compatible printer; an Advance Business Technology Keypad or Apple IIe Keypad; and a three button response box.

Software

A number of utility programs are included to aid in setting parameters for particular tests, in data management on stand-alone or network arrangements, and in data analysis. Generally, data for individual subjects is accumulated and stored in data files named for the task or subtask. These data files are DOS 3.3 text files. Utility programs include a CLEAR program to delete data from a data file without deleting the textfile from the directory; a CREATE program to set-up main data files and temporary data file buffers (for network systems); and a set of READ programs to allow transfer of data from all or part of individual data files to screen, printer, analysis program, etc.

Task Descriptions

Auditory Digit Span Task - This task relies on the Super Talker to warn the subject that the trial is about to begin ("Ready"), and then presents a series of digits followed by a bell. On hearing the bell, the subject enters the series using the keypad. As soon as the correct number of digits is entered, the stimulus series and the answer are shown on the screen. If the response is correct, another digit is added to the next series to be presented. If incorrect, the series is decreased by one. A second version of this test follows the same procedure except the length of the series remains constant. (SPEECH HEARING, MEMORIZATION)

Choice Reaction Time Task - This task has two parts, a pre-test and a post-test, both using the same parameters. One of three versions is selected (i.e., two-button, three-button or four-button reaction time). The experimenter selects a digit from one through nine as the stimulus for each button. A random stimulus is presented and the subject responds by rapidly pressing the corresponding button. Feedback is in the form of tones. One of five tones is presented to indicate the speed of response on a scale ranging from very good to very poor. The procedure is repeated until the trial or test limit set by the experimenter is

Choice Reaction Time Task (cont.)
reached. The post-test is then given until the criterion is reached again. (RESPONSE ORIENTATION)

Code Substitution Task - In this task, a random ordering of nine digits is paired with randomly drawn letters (from A-Z). A single letter from the set is shown above the coded pairs of letters and numbers. The subject then enters the appropriate digit for the letter displayed. The sequence repeats until the time limit for the test has been reached. (PERCEPTUAL SPEED)

Logic Task - This task uses the CRT to present a four-by-four matrix of sixteen boxes having a preassigned number sequence. The object of the test is to learn this sequence. The subject enters a box number via a numeric keypad. This "shades" the box (removing its number). If any previously selected boxes actually occur later in the sequence, they revert to their original display. The subject should learn that the number just entered comes before those that were renumbered. The number of setbacks and the time to complete the sequence are taken as data. (INDUCTIVE REASONING, MEMORIZATION)

Manikin Task - This task presents an image of a sailor holding a blue box in one hand and a red box in the other. The sailor stands on a box that matches the color of one of the boxes in the sailor's hands. The sailor may appear right-side up, up-side down, and facing either toward or away from the subject. The subject indicates as quickly as possible the hand in which the sailor is holding the box that matches the base, by pressing a key with the left or right hand. The number of 16-trial blocks is pre-selected by the experimenter. (VISUALIZATION, RESPONSE ORIENTATION, VISUAL COLOR DISCRIMINATION)

Math Test - The subject is first presented with addition, subtraction, multiplication, or division signs that are labeled for clarification. For each problem, a four-digit number is presented on line one and an arithmetic sign and a single digit is presented on line two. The subject performs the indicated mathematical operation and responds on an external numeric keypad. The test continues for a set number of trials. (NUMBER FACILITY)

Maze Task - The Maze Task requires the subject to move a dot through a maze (presented on a CRT) by controlling a joystick. The task is completed when the dot reaches the exit point. (CONTROL PRECISION, FINGER DEXTERITY)

Pattern Comparison Task - This task involves the presentation of two patterns simultaneously, with both left-hand and right-hand patterns occupying a space of 120(w) by 177(h) pixels. Patterns are enclosed inside borders that form a continuous box. There are eight randomly selected x, y coordinates for each pattern. If the patterns are not identical, they differ by at least three pixels. The subject must push the button marked "same" or the button marked "different" to end the trial. The test continues for a previously determined time limit. (PERCEPTUAL SPEED)

Spoke Task - The CRT display used for this test consists of thirty-two individual circles equally spaced around a circumference and one circle in the center. The circles each have a white light in the center which may be illuminated. Initially, the center circle is lighted. The subject taps the lighted center circle with the light pen. This light is extinguished and one outside circle light is illuminated. When the subject taps this light, it is extinguished and the center light is illuminated once more. When the subjects taps the center, the cycle is repeated, with the next sequential outside circle being lighted. This cycle is repeated until the subject has gone all the way around the outside circles in a clock-wise direction. (MANUAL DEXTERITY)

Sternberg Memory Scanning Task - This test program randomly selects target numbers (one to four digits in length) and displays these numbers for one second. The display is then cleared for a two second retention interval, after which a single digit is presented. The subject is to indicate if this digit was or was not in the target group. This task continues for the interval set by the experimenter. (PERCEPTUAL SPEED, MEMORIZATION)

Stroop-like Color Naming Tasks - There are three versions of this test, each of which uses the words RED, BLUE and GREEN as stimuli. In Version One, the words are randomly selected, plotted and presented on the screen as white stimuli on a dark background. The subject is to respond by pushing the red, blue or green button. Version Two presents the words as red, green or blue stimuli (e.g., the word RED printed in blue). The subject is to respond to the meaning of the word instead of the color in which the word is printed. Version Three is presented in the same format as Version Two. The subject is to respond to the color of the stimuli instead of the meaning of the word. All tasks continue until an experimenter-designated time limit is reached. (SELECTIVE ATTENTION, RESPONSE ORIENTATION, VISUAL COLOR DISCRIMINATION)

Visual and Auditory Grammatical Reasoning Task - In this test, a series of sentence-picture pairs is presented. The sentences are in the form of "A (does not) precede(s) B"; the pictures are an "A" and a "B" in either order. The subject responds with "T" if the sentence-picture pairs match and "F" if they do not match. The visual version presents the stimuli on the CRT screen, while the auditory version presents them via the Mountain Hardware Super Talker device and earphones. (DEDUCTIVE REASONING, SPEECH HEARING, WRITTEN COMPREHENSION)

Visual or Auditory Serial Addition Task - This task has two versions. The adaptive version allows subjects to input responses at their own pace. If the response is correct, the length of time to respond is decreased by a specified amount. If the response is incorrect, the length of time to respond is increased by the same amount. The constant version allows the subject only a specified length of time to input a response. The test itself is comprised of a random number between one and eight being plotted on the CRT or being spoken through the Super Talker. This is followed by a retention interval and the presentation of a second number between one and eight. The subject is to mentally add the two digits and then input the sum via the numeric keypad. (NUMBER FACILITY, MEMORIZATION, SPEECH HEARING)

Neurobehavioral Evaluation System (NES)

Baker, E. L., Letz, R. E., Fidler, A. T., Shalat, S., Plantamura, D. & Lyndon, M.A. (1985). Computer-based neurobehavioral evaluation system for occupational and environmental epidemiology: Methodology and validation studies. Neurobehavioral Toxicology and Teratology, 7, 369-377.

A computer-administered neurobehavioral evaluation system (NES) was developed to evaluate populations at risk for nervous system dysfunction due to environmental agents. The development of this test battery was influenced by previous tests developed for use in epidemiologic investigations. Additionally, a committee convened by the World Health Organization (WHO) and the National Institute for Occupational Safety and Health (NIOSH) have proposed a core set of neurobehavioral tests for use in epidemiological studies. Most of the tests are adaptations of pre-existing clinical instruments. The selection of tests was guided by clinical and epidemiologic experiences as opposed to theoretical considerations from the field of cognitive psychology.

This battery is comprised of twelve separate tasks. The tests evaluate verbal ability, psychomotor functioning, memory, visual spatial ability and mood--parameters which are potentially altered by exposure to neurotoxic agents. Combinations of the tests can be used or a standard administration sequence adopted. Five of the tasks in the battery are similar to tests within the seven-test WHO core test battery (World Health Organization, in press): symbol-digit substitution, digit span, simple reaction time, the visual memory test, and the mood scale. Additionally, a verbal paired-associate learning test and a continuous performance test have been specified by the WHO group as suitable supplements to the core set.

Prior to testing, each person completes a detailed work-health questionnaire regarding prior health conditions, prior jobs and job-related chemical exposures, current and past habits (e.g., alcohol and cigarette consumption history), demographic information, and current symptoms. The questionnaire is reviewed for accuracy and completeness by an interviewer. Immediately before administration of the test battery, a pre-test questionnaire designed to evaluate transient conditions (e.g., physical injuries, alcohol or drug consumption, sleep deprivation, emotional trauma) is also administered.

Hardware

The IBM PC was used for test development and initial administration. The programs will run on several IBM PC compatible machines including the COMPAQ. A joystick control having two pushbuttons is required for some task inputs.

Software

The software that administers these tests is written in IBM's Advanced BASIC. Separate files are developed for each subject and contain identification data and the test results. Each test in the battery is individually administrable. A screen menu permits the interviewer to choose the tests and test order for each subject. Timing of response latencies is accomplished by a software clock. Standard communications software permits data transfer over telephone or dedicated communication lines to larger computers for analysis using standard statistical software packages.

Task Descriptions

Continuous Performance Test (CPT) - This test measures sustained visual attention by having the subject press a button upon seeing a large letter "S" when it is projected onto a video display terminal. Letters flash briefly (for about fifty msec) on the screen at a rate of one per second for five minutes. Recording and storage of individual response latencies allows for computation of mean and standard deviation of reaction times by minute and for the full task. Omissive and commissive errors are also recorded. Using this data, indices of speed, task learning, and attention can be derived. (PERCEPTUAL SPEED, REACTION TIME)

Digit Span - The auditory version of this widely-used clinical test is part of the Wechsler Adult Intelligence Scale and Wechsler Memory Scale. In the NES version, the subject must enter into the computer progressively longer series of digits which have been presented visually at a rate of one per second by the computer. New digit sequences are created at each span length. After incorrectly responding to two trials at a span length, the task changes such that the subject must enter digits in an order reversed from that presented by the computer. Previous studies of solvent and lead toxicity have utilized this test as a measure of short-term memory and attention. (MEMORIZATION)

Hand-Eye Coordination Test - This test requires the subject to use a joystick to trace over a large sine wave pattern on the video display terminal. The computer moves a cursor horizontally at a constant rate, while the individual controls the vertical motion of the cursor with the joystick. Deviations from a set line as mean absolute error and root mean square error are recorded and constitute measures of coordination ability. This task evaluates dexterity, a function found to be disrupted in previous studies of various neurotoxic agents. (CONTROL PRECISION, FINGER DEXTERITY)

Memory Scanning Test - The subject is shown a series of digits and then must indicate whether a test digit comes from the previously presented set. Responses are scored as correct/incorrect and response latencies are recorded. The set size of digits to be presented is varied from two to five and regression techniques are used to assess cognitive encoding and motor processing, positive and negative latency, and memory scanning time. The test measures the actual processing time required to recall previously stored (i.e., learned) information and has been shown to be sensitive to chronic mercury exposure. (MEMORIZATION, PERCEPTUAL SPEED)

Mood Scales - Subjects are asked to rate their feelings over the previous week on each of twenty-five adjectives or phrases. By combining ratings, these twenty-five individual items yield a five-dimensional mood profile. Prior studies of lead toxicity have shown that such an approach is useful and sensitive in the evaluation of central nervous system effects of occupational lead exposure.

Paired-Associate Learning Test (with delayed recall) - This task is similar to the Digit Span task, and is designed to evaluate short-term verbal memory. Word pairs are read from the visual display screen at a rate controlled by the computer. The series of words is presented three times with varying internal order. Scores, consisting of the number of correct associations, are given for each trial. An additional trial containing the same words is given at the end of the testing session to evaluate memory encoding and intermediate recall. (MEMORIZATION)

Pattern Memory Test - This test of short-term visual memory involves the brief presentation of a block-like pattern similar to those used in the pattern recognition test followed by three similar figures, one of which is identical to the original pattern. The degree of correspondence of the two incorrect patterns to the correct one varies. (MEMORIZATION, PERCEPTUAL SPEED)

Pattern Recognition Test - This task requires that the subject identify which of three block-like patterns differs from two other figures which are identical. The task requires intact visual organization ability, a function which is required for the perception of complex visual material and which represents an aspect of higher cortical function. (PERCEPTUAL SPEED)

Simple Reaction Time - This task requires the individual to press a button when seeing a large "0" on the screen. The interstimulus interval is varied randomly between 2.5 and 7.5 seconds to reduce anticipation effects. Data are recorded as individual reaction times over the presentation of sixty stimuli and the response latencies are averaged over blocks of twelve trials. (REACTION TIME)

Symbol-Digit Substitution Test - This task is similar to the Digit-Symbol Substitution test from the Wechsler Adult Intelligence Scale (WAIS). The Digit-Symbol test, which evaluates speed and coding abilities has been found useful in prior epidemiologic studies of individuals exposed to lead, carbon disulfied, and solvent mixtures. Nine symbols and digits are paired at the top of the screen and the subject has to press the digit keys corresponding to a reordered test set of the nine symbols. The time required to complete each symbol-digit set and the number of digits incorrectly matched are recorded. Five sets of nine symbol-digit pairs are presented in succession. The pairing of symbols with digits is varied between sets to avoid learning. (PERCEPTUAL SPEED)

Visual Retention Test - The machine first presents a test figure followed by four similar figures from which the individual must select the figure previously seen. The score consists of the number correct and the average response time for correct and incorrect responses. (PERCEPTUAL SPEED)

Vocabulary - Twenty-five words are presented and the subject is asked to select the synonym from a set of four words. This test is said to provide a stable index of CNS function. (WRITTEN COMPREHENSION)

PORTA-BAT, Version 4

Basic Attributes Tests (BAT) - Version 4. Hardware, System, & Individual Test Descriptions (June, 1985). Brooks AFB, TX: U.S. Air Force Human Resources Laboratory Manpower and Personnel Division.

In 1983, the Air Force Human Resources Laboratory decided to replace the older Basic Attributes Tests (BAT) and testing stations with modern, high speed super-microcomputer driven, transportable testing units. The Porta-Bat is a complete, integrated, portable testing and training laboratory being validated by AFHRL. The battery is designed to measure a variety of information processing abilities and personality characteristics that are considered important in selecting flight training candidates.

Hardware /Software

The PORTA-BAT features high speed graphics, rugged single and two-axis joysticks, data entry keypad, fixed and removable hard disk drives, and a rugged station enclosure. The station enclosure is a six foot heavy guage aluminum enclosure with doors on the front and the back. The desk-top cabinet slides into the station enclosure on rails and is fastened in place. The front doors open 90 degrees and a top panel slides out to form a visual screen to both sides and above the subject. A lower panel hinges out to the floor and leg positioners precisely fix the location of the chair provided with the unit. Two industrial quality joysticks with precision potentiometers are included as part of the system. The total weight of the complete unit is under three hundred pounds. With a suitable transformer the PORTA-BAT may be used with 220 volts and 50 Hz in addition to the standard 120 volts and 60 Hz electricity.

The PORTA-BAT features a powerful super microcomputer with very high speed, high resolution graphics and communications features that permit networking or on-line data transfer to a monitoring station during testing. Since the operating system is a direct adaptation of UNIX and most standard compilers are available with the PORTA-BAT, software may be developed by in-house personnel to perform desired testing/training capabilities. The PORTA-BAT supports serial or parallel printers and up to three additional terminals for concurrent program development, general purpose computing, or analysis of test data. PORTA-BAT comes equipped with a high level graphics software package with C and FORTRAN callable graphics functions, the Regulus operating system, a C compiler, a FORTRAN compiler, and the software necessary for interfacing all attached devices.

The system was built around the Motorola MC68010 processor and REGULUS, a real-time UNIX-compatable operating system. From a basic computer commercially offered by Alcyon Corporation, Technical Solutions, Inc. (TSI) developed a custom computer that performs the laboratory functions. The processor, a model APS, was first configured with both a five Megabyte fixed hard disk and a five Megabyte removable diskcartridge so that the operating system and the permanent software are resident on the system, and data gathered may be easily transported via the removable disk. The processor memory was increased to 512 Kilobytes to accomodate the graphics software and large applications program. A graphics co-processor was added so that the graphics vector stroke generation was offloaded from the main processor, allowing for increased functional capability in the main processor and faster graphics display generation. This co-processor was installed on an internal Q-BUS and appears as a peripheral to the main processor. The video section of the CRT display was modified to operate in either a graphics mode or alphanumeric mode under software control. A parallel input-output board and an Analog-to-Digital converter were added to the Q-BUS together with a custom designed TSI adapter-driver board. The parallel input/output board allows for sixteen inputs and sixteen outputs of TTL logic levels to the computer. It is used in the PORTA-BAT for control of the lights in the keypad, keypad responses, switch inputs from the two-axis joystick, and the generation of interrupts. The ADC is used for the measurement of joystick movement. Thirteen additional channels exist for custom applications and application-specific requirements. The adapter-driver board provides signal routing, signal conditioning, and interfacing functions as well as the generation of "pink" noise to drive a headphone. The noise level may be set by on-board adjustments, and is used together with the PORTA-BAT headphone set to eliminate background sound distractions.

The graphics display of the PORTA-BAT is a 481 X 530 monochrome display with four image planes and grey level capability. Capable of drawing over 40,000 vector strokes per second, the graphics processor produces twenty full-screen updates per second refreshed at 60 Hz.

Task Descriptions

Note: The bracketed terms represent the original author's designation of the "psychological factors" measured in performance of the task.

Activities Interest Inventory [Survival attitudes] - The subject is presented with eighty-one pairs of activities and is asked to choose between them. The task is designed to sample the subject's interest in various activities. The subject is told to assume he/she has the ability necessary for each activity.

Automated Aircrew Personality Profiler [Personality factors to be extracted] - This task examines the subject's attitudes and interests and is targeted for aircrew work. The subject is presented with 200 questions, each requiring a choice between two alternatives. The subject is instructed not to spend time pondering, but to give the first, natural answer as it comes.

Decision-Making Speed [Simple choice reaction time] - The subject is presented with one of a number of alternative signals. The subject must respond to the signal with the matching response as quickly as possible. Task difficulty increases when more alternative signals may potentially be presented. There are four subtasks within the main task. (RESPONSE ORIENTATION)

Dot Estimation [Compulsiveness vs. Decisiveness] - The subject is presented with two boxes containing an arbitary number of dots. One of the two boxes has one more dot than the other. The subject's task is to determine as quickly as possible which of the two boxes has the greater number of dots. (PERCEPTUAL SPEED)

Embedded Figures [Field dependence/independence] - The subject is presented with a simple geometric figure and two complex geometric figures. The subject's task is to decide which of the two complex figures has the simpler figure embedded within it. The subject indicates the choice by pressing a button corresponding to that figure. (FLEXIBILITY OF CLOSURE)

Encoding Speed [Verbal processing ability] - The subject is presented with two letters. S/he is required to make a same/different judgment on the letter pair based on either physical identity (ex: AA vs. Aa) or name identity (ex: AA vs. AH). The latency of the encoding judgment provides a measure of the speed of the encoding process. (PERCEPTUAL SPEED)

Immediate/Delayed Memory [Continuous short-term memory storage and retrieval] - The subject is presented with a sequence of digits and is required to press a button corresponding to the item which occurred one or two digits previously. First, the digits are presented for 0.5 seconds followed by a two second interstimulus interval. Then, the digits are presented followed by a five second interstimulus interval. (PERCEPTUAL SPEED, MEMORIZATION)

Item Recognition [Short-term memory store, search and compare operations] - A row of one to six digits is presented on the CRT. After a brief delay, a single digit appears on the screen. Subjects are instructed to remember the initial series of digits, then to decide if the single digit is one of those represented in the initial series. The subjects respond by pressing either a "yes" or "no" button. (PERCEPTUAL SPEED, MEMORIZATION)

Mental Rotation [Mental-spatial transformations and classification] - The subject is sequentially presented with a pair of letters and asked to make a speeded same/different judgment. The letter pair may be either identical or mirror-images, and the pair may be in the same or different spatial orientation. (VISUALIZATION, PERCEPTUAL SPEED)

Perceptual Speed [Information input efficiency] - The subject is presented with a sequence of four digits and is required to respond by pressing response pad buttons in the same order as the presented digits. (PERCEPTUAL SPEED, RESPONSE ORIENTATION)

Psychomotor Device Tests [Low to moderate order tracking, time sharing ability] - The first subtask is a two-hand coordination task. The subject controls the vertical and horizontal movement of a small cross using the left and right joy sticks, respectively. In the second subtask, which assesses complex coordination, the subject uses a dual axis joystick to control the horizontal and vertical movement of a small cross. The subject's task is to keep the small cross centered on a large cross fixed at the CRT's center, while at the same time centering the rudder bar at the base of the CRT. (CONTROL PRECISION, FINGER DEXTERITY, TIME SHARING, MULTILIMB COORDINATION)

Risk Taking [Effects of uncertainty on decision-making] - The subject is presented with a matrix of ten boxes (in two rows of five) and is told that nine of the boxes contain a reward and one is a disaster box. The subject selects one box at a time. If the selected box contains a payoff, the subject gets to keep it. If the disaster box is selected, the subject loses all of the payoffs acquired. The average number of boxes selected provides an index of the subject's propensity for taking risks when making decisions.

Self-Crediting Word Knowledge [Self-assessment ability/self-confidence) - The subject is presented with a "target" word and five other words. The subject must choose which one of the five words means most nearly the same as the "target". There are three blocks of ten questions each and the target words become increasingly more difficult with each succeeding block. The subject is informed of this difficulty and is required to make a bet prior to each block, which reflects how well s/he expects to do. (WRITTEN COMPREHENSION)

Task Battery Introduction - This is an interactive subprogram which collects such information as the subject's identity, age, gender, personal history, and attitudes about flying.

Time Sharing [Higher order tracking] - The subject must anticipate the movement of a marker on a visual display and operate a control stick to counteract the movement and keep the marker aligned with a fixed central point. After a fixed number of trials, the subject is then required to track while cancelling digits which appear at random intervals and locations on the display. S/he cancels the digits by pressing the corresponding buttons on the keypad. The dual task trials occur in two blocks of three trials each which are then followed by additional tracking-only trials. (TIME SHARING, RATE CONTROL, FINGER DEXTERITY)

Taskmaster System - NIOSH Performance Battery

Wheeler, D.D., & Rosa, R. (1984). Instructional manual. Taskmaster System / NIOSH Performance Battery. Version 1984 July 20. Cincinnati, OH: National Institute of Occupational Safety and Health, Division of Biomedical and Behavioral Sciences.

The Taskmaster system is a set of microcomputer programs designed to administer a battery of performance tasks to a human subject without the presence of an experimenter. The Taskmaster system can be set up to administer any subset of the available tasks. The tasks can be adjusted for the specific requirements of the study being conducted. For the Grammatical Reasoning task, for instance, both the difficulty of the items and the number of blocks of trials can be specified.

Taskmaster is intended for applications involving repeated testing of subjects over an extended period of time. An example would be a study of the effects of different work schedules. Subjects would be able to administer the test battery to themselves both before and after work.

Hardware

The Taskmaster system is designed to run on the Kaypro II microcomputer. The system uses software loops for timing, calibrated with a 2.5 MHz CPU clock. The programs will have to be recalibrated if the system is to be used on the newer Kaypro II. The Taskmaster requires two hardware accessories: (1) a clock/calendar, and (2) a custom designed accessory box with various features and items, including the following: a) three push buttons for obtaining timed responses from the subjects, b) a white noise generator with output to headphones, and c) a probe with a metal tip and a metal opening slightly larger than the tip.

The NIOSH Performance Battery is currently being re-written for IBM compatible computers.

Software

The Taskmaster system is supplied free upon request. Two blank disks must be sent to the authors in order to copy the NIOSH software.

Task Descriptions

Arithmetic Speed - This task consists of a series of single digit addition problems. The subject is only required to type in the last digit of the sum. The task is subject paced. The experimenter can increase the difficulty level by specifying an optional single digit constant. This constant is presented briefly (three seconds) to the subject before the series of trials. The subject must then add this constant to the sum on each trial. The task lasts for a specified amount of time rather than a fixed number of trials. Elapsed time, trials completed, and number of errors are recorded. (NUMBER FACILITY, MEMORIZATION)

Free Recall of Word List - This task presents a list of words to the subject, one at a time, and then tests free recall memory by requiring the subject to type them on the keyboard. A time limit for recall can be specified by the experimenter. The program counts the number of words correctly recalled by the subject. (MEMORIZATION)

Grammatical Reasoning - This task measures the subject's speed and accuracy on a complex task involving both memory and reasoning. For each trial, the following sequence occurs: 1) a stimulus string of letters (e.g., JLN) is displayed for two seconds, 2) the screen is cleared for a three second retention interval, then 3) a test statement appears on the screen (e.g. N precedes L), and finally, 4) the subject indicates whether the test statement is TRUE or FALSE by pressing the appropriate button. Incorrect and non-responses are counted as errors. Means and standard deviations of reaction times are reported for each block of sixteen trials. (DEDUCTIVE REASONING, MEMORIZATION, WRITTEN COMPREHENSION)

Grammatical Reasoning with Reaction Time - This task consists of the Grammatical Reasoning task with a simultaneous auditory reaction time task. The dual task's only difference from the Grammatical Reasoning task is that the subject is instructed to put on the headphones during the task and to push a button whenever a noise burst occurs. (DEDUCTIVE REASONING, TIME SHARING, REACTION TIME, WRITTEN COMPREHENSION)

Hand Steadiness - This task requires the subject to hold the small metal tip of a probe within a small (1/8 inch) metal fitting. The subject's goal is to minimize the contact between the probe and the fitting. The program records the percentage of time in contact. (ARM-HAND STEADINESS)

Noise Fusion - This task estimates the detection threshold of a silent gap between two noise pulses. Trials are presented to the subject through headphones. On each trial, the program presents two noise bursts (about 108 ms long) separated by a gap of silence. If the gap is short enough, the subject hears the two bursts as a single longer burst. The subject is to indicate after each trial whether they heard one or two bursts. (GENERAL HEARING)

Questionnaire Tests - This program can administer questionnaires consisting of multiple choice or rating-scale items. It can also ask open ended questions or those requiring numeric responses, such as temperature.

Reaction Time - This program can present three different kinds of reaction time tasks: 1) simple visual reaction time, 2) choice visual reaction time, and 3) simple auditory reaction time. Means and standard deviations are reported for each block of trials. (REACTION TIME, RESPONSE ORIENTATION)

Response Alternation - This task measures the speed with which the subject can alternate between pushing two buttons. When the subject begins pushing either button, the program counts the number of alternations (press and release of each of the two buttons) until the end of the time period. (FINGER DEXTERITY)

Time Estimation - This task requires that the subject indicate when a specified number of seconds have passed. The subject is instructed not to count during the interval. The program first tells the subject the length of time to be estimated. The subject pushes the "press" button to begin and terminate intervals

Zip Code Typing - This task was designed to simulate a boring and repetitious work environment. The program randomly generates five digit numbers and displays them, and the subject must simply type in the digits. Immediate "OK" or "Error" messages are displayed for each trial. If the subject's accuracy is below ninety percent, the program displays the message "Please try harder". (SELECTIVE ATTENTION)

Unified Tri-Services Cognitive Performance Assessment Battery (UTC-PAB)

Englund, C.E., Reeves, D.L., Shingledecker, C.A., Thorne, D.R., Wilson, K.P., & Hegge, F.W. (1986). Unified Tri-Service Cognitive Performance Assessment Battery (UTC-PAB). *

* Our report is based on a pre-publication document supplied by Dr. William Perez of Systems Research Laboratories of Dayton, Ohio.

The purpose of this battery is to provide a standardized metric that is responsive to required military-mission abilities and skills and that will be a sensitive instrument for detecting performance decrements due to the use of biomedical treatment drugs.

Tasks comprising this battery are largely derived from components of the Army (WRAIR-PAB), Navy (PETER; NAVAL CCT) or Air Force (CTS) batteries detailed elsewhere in this report. UTC-PAB should be available for use in early 1987.

Hardware/Software

The UTC-PAB is currently written for IBM compatible computers in C language. Although no formal descriptions of special hardware are yet available, use of the UTC-PAB is anticipated to require such response devices as a button box, key pad, hand-held push button switch and rotary knob.

Task Descriptions

Note: Task descriptions include mention of a "construct" proposed by the UTC-PAB authors in addition to the ability/abilities designation assigned by the current authors and parenthetically detailed for each task.

Alpha-Numeric Visual Vigilance Task - Construct: vigilance [sustained choice RT] - Random alphabetic characters or numbers are presented at random intervals ranging between six and fourteen seconds. Subjects press a hand-held, push button switch whenever an "A" or "3" appears. (PERCEPTUAL SPEED, RESPONSE ORIENTATION)

Code Substitutions - Constructs: perceptual speed/associative learning ability - This test is derived from a paper and pencil test contained in the Wechsler Adult Intelligence Scale. The subjects see a string of nine letters and a string of nine digits displayed across the screen. The strings are arranged so that the digit string is immediately below the letter string with one digit corresponding to each letter. A test letter is presented at the bottom of the screen and the subject is to indicate which digit corresponds to the test letter in the displayed study strings by pressing the appropriate response button. (PERCEPTUAL SPEED)

Continuous Recall Task - Constructs: encoding and recall/working memory - This task indexes the operator's ability to encode and store information in working memory. It requires serial encoding and recall under a changing memory state. The memory test consists of a random series of visual presentations of numbers which the operator must encode in sequential fashion. As each number is presented for encoding, a probe number is simultaneously presented. The operator must compare this probe number to a previously presented item at a pre-specified number of positions back in the series and indicate if that item is the same or different from the probe number. (PERCEPTUAL SPEED, MEMORIZATION)

Dichotic Listening Task - Construct: auditory selective attention - This task requires subjects to attend to auditory information (a specific set of letters and digits) presented to one ear while ignoring similar information presented to the opposite ear, and then after considering an auditory cue, to switch attention rapidly to the previously unattended ear, or maintain attention to the previously attended ear channel. Subjects must attend to auditorily presented information and respond to the numbers presented on the command ear channel using a keypad. The numbers are touched on the keypad in the order of their occurrence in the command ear. (AUDITORY ATTENTION, SELECTIVE ATTENTION)

Four-Choice Serial Reaction Time - Constructs: encoding, categorization, response selection and execution - This task presents a blinking "+" (plus sign) imposed on the cursor in one of four quadrants of a CRT. The subject presses one of four keys, each corresponding to one of the four quadrants, to indicate the location of the blinking "+". (RESPONSE ORIENTATION)

Grammatical Reasoning (Symbolic) - Construct: logical reasoning - Stimulus items are sentences of varying syntactic structure accompanied by a set of symbols (e.g. *,@, #) presented simultaneously. The sentences must be analyzed to determine whether they correctly describe the ordering of the symbols in the symbol set. Task demand is influenced by the amount and complexity of grammatical analysis. (DEDUCTIVE REASONING)

Grammatical Reasoning (Traditional) - Construct: logical reasoning - This a linguistic task requiring knowledge of English grammar and syntax, and the ability to determine whether various simple sentences and their grammatical transformations correctly describe the relational order of two objects. On each trial the letter pair "AB" or "BA" is displayed along with a statement that correctly or incorrectly describes the order of the letters within the pair. The subject decides as quickly as possible whether the statement is true or false and presses the correct button on the button box. (DEDUCTIVE REASONING, WRITTEN CONPREHENSION)

Interval Production Task - Construct: response timing - This task requires subjects to generate a series of time intervals by tapping a finger key at a rate of one to three responses per second. The goal of the task is to maintain equal time intervals by tapping at as regular a rate as possible. (FINGER DEXTERITY)

Linguistic Processing - Construct: visual/verbal-phonetic coding - This task is a synthesis of letter matching and generic depth of processing tasks. It is a standardized loading task that places demands on resources concerned with processing and transformation of linguistic information, and requires classification of letter or word pairs. Letter or word pairs are presented on a CRT, and subjects are instructed to respond "Same" if the items match on the dimension in question or "Different" if otherwise. There are three levels of task demand: (1) physical letter match - in which letter pairs must be physically identical to match (low demand); (2) category match - requiring that both letters be either consonants or vowels (moderate demand); and (3) antonym match - in which only words opposite in meaning constitute a match (high demand). (PERCEPTUAL SPEED, INDUCTIVE REASONING for antonyms)

Linguistic Processing-Choice Reaction Time Combination - Construct: time sharing ability - This "dual task" paradigm represents the combination and simultaneous presentation of the Linguistic Processing Task (Category Match) and the Four-Choice Reaction Time Task. The same stimuli used in single-task conditions are used in this combination with the restrictions noted. (RESPONSE ORIENTATION, TIME SHARING, PERCEPTUAL SPEED, INDUCTIVE REASONING for antonyms)

Manikin Test - Constructs: spatial orientation/rotation ability - This test uses high resolution graphics to display a sailor holding a blue box in one hand and a red box in the other hand. The sailor stands on a base which is a rectangular box (red or blue) that matches the color of one of the boxes in the sailor's hands. A display of the sailor and base may appear right side up, upside down, front facing the subject, or back facing the subject. At the bottom of the base "4-left" and "6-right" are printed to indicate the keys that represent left and right. If the subject thinks the box in the sailor's left hand matches the color of the base, s/he responds left, and vice-versa if the match is on the sailor's right side. (VISUALIZATION, VISUAL COLOR DISCRIMINATION)

Mathematical Processing Task - Constructs: number facility/general reasoning - This is a loading task that is designed to test information processing resources that are concerned with arithmetic operations and value comparisons of numeric stimuli. Subjects perform one or more addition and/or subtraction operations on visually presented single digit numbers. Subjects respond on a two button keypad to indicate whether the total is greater or less than the pre-specified value of five. (NUMBER FACILITY, MEMORIZATION)

Matrix Rotation Task - Constructs: spatial orientation/rotation and short-term memory - A series of five-by-five cell matrices are presented (one at a time in the center of the CRT) with five illuminated cells per matrix. The subject is required to compare successive displays and determine if they are the same or different from the immediately preceding illuminated matrix. Response requires pressing a "1" key for "Same" and a "2" key for "Different". (VISUALIZATION, PERCEPTUAL SPEED, MEMORIZATION)

Memory Search Task - Constructs: encoding, categorization, response selection and execution (visual and auditory modalities/short-term working memory) - This task requires a subject to maintain in memory a "study set" of alphabetic characters. Following the presentation of the study set, individual probe letters are presented to the subject for classification as members of the study set or non-members. Subjects respond by pressing the appropriate key on a two-button keypad. Six versions fo the task are available in the battery: Visual Fixed set, Visual Mixed set, Visual Varied set, Auditory Fixed set, Auditory Mixed set, and Auditory Varied set. (PERCEPTUAL SPEED, MEMORIZATION)

Pattern Comparison (Simultaneous) - Construct: perceptual speed/pattern recognition - The subject is presented with two, eight-dot patterns next to each other on the screen. The subject indicates whether or not the two patterns are identical by pressing the appropriate response button. (PERCEPTUAL SPEED)

Pattern Comparison (Successive) - Constructs: perceptual speed/short-term spatial memory A random pattern of "dots" is presented on a screen and is followed by a blank retention interval. A second pattern is then presented and the subject presses a button to indicate whether the second pattern is the same or different than the first. (PERCEPTUAL SPEED)

Short-Term Memory - Construct: short-term recall - In this task, the subject is presented with a string of consonants on a CRT. This target string presentation is followed by a blank screen for two seconds and then a new string of letters is presented. The second string is the test string. The subject is required to indicate whether the test string is identical to the target string. The subject responds by pressing one of two buttons labeled "same" or "different", respectively. (PERCEPTUAL SPEED, MEMORIZATION)

Spatial Processing Task - Constructs: spatial orientation/rotation and short-term memory - This task requires the operator to view a series of histograms presented one at a time. The operator must determine whether the second histogram in each set of two is identical to the first and respond either positively or negatively on a two-button keypad. Target and comparison histograms are marked with the numbers 1 and

Spatial Processing Task (cont.)
2, respectively, so that subjects can keep track. Low task demands are placed on the operator when two bar histograms are presented with comparison items in the 0-degree orientation. Four bar stimulus pairs with comparison items at the 90-degree and 270-degree orientation represent a moderate loading condition. Finally, six bar comparison histograms presented at the 180-degree orientation impose relatively high demand on the operator. (PERCEPTUAL SPEED, VISUALIZATION)

Sternberg Tracking Combination (Dual-Task Paradigm) - Construct: time sharing ability - This "dual-task" represents a combination of the Memory Search Task (Visual-Fixed set) and the Unstable Tracking Task. This combination requires simultaneous executions of responses as described for each task. All subjects are required to track with their left hand and respond to the memory search task with their right hand. (RESPONSE ORIENTATION, TIME SHARING)

Stroop Test - Construct: interference susceptibility to response competition interference - There are three versions of this test, all of which use the words red, blue, and green and their respective colors. In the Control Condition (Version 1), individual words are displayed on the CRT in matching colors and the subject is required to press a corresponding button as quickly as possible. This is intended to be used in conjunction with the Interference Condition (Version 2) to provide an estimate of susceptibility to response interference. The Control version used by itself can serve as a choice reaction time test. In the Interference Condition, the display color and the words are sometimes different and sometimes the same. The Combined Condition (Version 3) is designed to require only one test to measure response interference as compared to traditional testing procedures requiring two tests. A word is displayed in a particular color and the subject is required to press the appropriate response button indicating the display color. The displayed color is either red, blue or green. The test word is either an interference word or a control word. The interference words are red, blue, and green, and the control words are gun, door, and house. If the word being presented is an interference word, then the word and the display color are different; otherwise, the word and display color are randomly paired. (SELECTIVE ATTENTION, RESPONSE ORIENTATION)

Time Wall - Construct: time estimation - This is a non-verbal time estimation task in which a small object moving at a constant speed passes behind an opague barrier and the subject must estimate the moment when the object will reappear. Movement is vertical rather than horizontal for purposes of visual field symmetry. The barrier contains a hole or notch the same shape and size as the object, and the subject estimates the moment when the entire notch will be filled. The subject responds by pressing any button on the button box.

Two-Column Addition - Construct: number facility - This is a subject-paced mental arithmetic test that measures the ability to sum simple addition problems with speed and accuracy. Sets of three two-digit numbers are presented simultaneously in columnar format in the center of the CRT. The subject is required to sum as rapidly as possible and to enter the answer, most significant digit first, via a keypad. (NUMBER FACILITY)

Unstable Tracking Task - Construct: critical/unstable tracking - This is a loading task designed to place variable demands upon human information processing resources dedicated to the execution of rapid and accurate manual responses. Subjects view a fixed target centered on a video screen. A cursor moves vertically from the center of the screen, and the operator attempts to keep the cursor centered over the target area by rotary movements of a control knob. (RATE CONTROL, FINGER DEXTERITY)

Visual Probability Monitoring Task - Constructs: spatial scanning/signal detection - Subjects are required to monitor one, three or four computer generated displays having the appearance of electromechanical dials. Each display consists of a row of six vertical hashmarks with a seventh mark offset above the others to indicate the center of the dial. A number appears to the left of each dial to identify it, and each dial is circumscribed by a rectangular "bezel". Under normal (non-signal) conditions, a pointer located below the hashmarks moves from one position to another in random fashion to simulate the pointer fluctuations on an actual dial. At unpredictable intervals, the pointer on a display begins to move non-randomly, staying predominantly to the left or right half of the dial. These biases in the pointer movement are the signals to which subjects are instructed to respond. By pressing an appropriate response key, biased dials are corrected to the non-signal (random pointer movement) state. (TIME SHARING, some performance strategies may utilize PERIPHERAL VISION)

Visual Scanning - Construct: perceptual speed - This is a visual search and recognition task. In this task, target and distractor objects are letters of the alphabet arranged as R rows (e.g., twenty-five) of C columns (e.g., five). The subject scans the array in normal reading order (left-to-right, top-to-bottom) and presses a button or key as soon as s/he detects the pre-determined target letter. (PERCEPTUAL SPEED, FLEXIBILITY OF CLOSURE)

Walter Reed Army Institute for Research Performance Assessment Battery (WRAIR-PAB)

Thorne, D.R., Genser, S.G., Sing, H.C., & Hegge, F.W. (1985). The Walter Reed Performance Assessment Battery. *Neurobehavioral Toxicology and Teratology*, *7*, 415-418.

This battery was designed to be a research tool for following performance changes over time, treatments, dosages or levels. WRAIR-PAB has been applied to studies of sleep deprivation, sustained performance, jet lag, heat stress, physical fatigue, physical conditioning, atropine use, hypoxia and sickle cell disorders.

Tasks chosen for inclusion in the battery are said to (1) represent a reasonable, realizable sample of elemental skills generally regarded as underlying many real-world tasks; (2) have the ability to be administered briefly and repeatedly; (3) be appropriate for computer implementation and (4) have a known or expected sensitivity to physiological, psychological or environmental variables.

Hardware

The Apple version requires a 48K Apple II, II-Plus, or IIe with a monochrome monitor, one or two floppy disk drives and a programmable timer module (California Computer Systems 7440 A).

The IBM compatible version requires a 64K Corona portable computer with internal monochrome monitor or an IBM PC with monochrome or color monitor and adapter, one or two floppy disks and a Tecmar Labmaster or Labtender timer card.

A simple hardware modification must be added to the Apple machine in order to blank and unblank the screen instantly in synchrony with the video frame rate (the vertical synchrony pulse).

Software

Applesoft Basic under Dos 3.3. or Microsoft GWBASIC under MS-Dos 2.0. This software program is available from the Department of Behavioral Biology, WRAIR, Walter Reed Army Medical Center, Washington D.C. free of charge to agencies and professionals in the life sciences.

The battery does not require touch typing skills, but does require the ability to read and perform mathematical operations above the grade school level.

Task Descriptions

Digit Recall - A test of short-term memory capacity. Nine random digits are displayed in a row across the center of the screen for one second. After a three second blank retention interval, eight of the nine digits are re-displayed in a different order. The subject then enters the missing digit. (MEMORIZATION, PERCEPTUAL SPEED)

Encoding/Decoding - The subject is given a series of letters to be translated into numerical map co-ordinates or vice-versa, by means of a moderately complicated double set of code keys that remain the same from trial-to-trial but change from successive test sessions. The task typically runs for three minutes. (DEDUCTIVE REASONING)

Four-Choice Serial Reaction Time - The subject is given a box having four light emiting diodes in a square array mounted above four push buttons in a similar square array. Single lights are illuminated randomly and the subject is to press the corresponding button as quickly as possible, thereby initiating the next trial. The task traditionally runs for eight minutes. It requires a California Computer System Model 7720 parallel interface card and some custom hardware. (RESPONSE ORIENTATION)

Logical Reasoning - An exercise in transformational grammar. The letter pair "AB" or "BA" is presented along with a statement that correctly or inorrectly describes the order of the letters within the pair. The subject decides whether the statement is true (same) or false (different) and presses the "S" or "D" key accordingly. (DEDUCTIVE REASONING, WRITTEN COMPREHENSION)

Mood Activation Scale - Subjects are presented with 65 adjectives and asked to indicate on a five-point scale the extent to which each adjective reflects their current feelings. The adjectives were selected to represent positive or negative *affect*, and positive or negative *activation*. This scale was developed by merging two previously separate lists, Thayer's Activation-Deactivation Check List (Thayer, 1967) and Zuckerman's Multiple Affect Adjective Check List (Zuckerman, Lubin, Vogel, & Valerius, 1964), with three consistency-checking items (dizzy, compliant, cooperative) which are deemed to be orthogonal to mood and subjective activation.

Mood Scale II - An abbreviated three-point scale consisting of thirty-six adjectives representing six factors identified as Anger, Happiness, Fear, Depression, Activity and Fatigue.

Pattern Recognition I - A spatial memory task. A random pattern of dots (asterisks) is displayed for 1.5 seconds followed by a 3.5 second blank retention interval and then by presentation of a second dot pattern that may be the same or different as the first. The subject indicates whether they perceive these two patterns to be the same (S) or different (D). (PERCEPTUAL SPEED, MEMORIZATION)

Pattern Recognition II - A more difficult version of Pattern Recognition I. The pattern consists of sixteen dots, of which either two or no dots change. (PERCEPTUAL SPEED, MEMORIZATION)

Serial Add/Subtract - A machine-paced mental arithmetic task requiring sustained attention. Two randomly selected digits and either a plus or minus sign are displayed sequentially in the same screen location. The subject performs the indicated operation and enters the least significant digit of the result. If the result is negative he adds ten to it and then enters the positive single digit remainder (for example, "3 / 9 / - " equals -6, so enter "4"). The digits and signs are presented for approximately 250 msec, separated by approximately 200 msec, with the next trial beginning immediately after the key entry. (NUMBER FACILITY, MEMORIZATION)

Six-Letter Search - Same as for the Two-Letter Search, but with six target letters instead of two. Letter search tasks are usually run for at least two minutes each. (PERCEPTUAL SPEED, FLEXIBILITY OF CLOSURE)

Time Estimation I - An object which is moving at a constant velocity passes behind a barrier and the subject must estimate the moment when it will re-appear. The barrier is a white rectangle filling the bottom third of the display area and which has a black notch centered along its bottom edge. The moving object is a white square of the same size as the notch and which appears at the top center of the display. This object descends at a rate such that it would coincide with the notch exactly ten seconds later. The square appears to pass behind (or into) the barrier, after which the timer continues to run but nothing else occurs until the subject presses a key to indicate his/her estimate of when the square will fill the notch. Neutral

Time Estimation I (cont.)
feedback that a response has been registered is provided by changing the notch to white for 500 msec after the response.

Two-Column Addition - A subject-paced mental arithmetic task. Five two-digit numbers are presented simultaneously in column format in the center of the screen. The subject determines their sum as rapidly as possible and enters it via the keyboard, beginning with the hundreds digit. The task is typically run for three minutes. (NUMBER FACILITY)

Two-Letter Search - A visual recognition task. Two target letters are presented at the top of the screen, along with a string of twenty letters in the middle of the screen. The subject presses the "S" key if both of the target letters are present in the longer string, and the "D" key if one or more letters are missing. (PERCEPTUAL SPEED, FLEXIBILITY OF CLOSURE)

Visual Scanning - A search task involving minimal memory loading and separating scanning times from preparatory and response execution times. An asterisk serving as a fixation point and one-second warning signal is displayed three character positions to the right of top center. It is replaced with a five-column by twenty four-row array of random distractor letters containing one occurrence of the target letter "K". The subject scans down the array, presses the "5" key immediately upon detecting the target, and then has three seconds to identify the target's row. Correctness of identification is determined in one of two ways: (1) pressing the key causes a column of numbers from 01 to 24 to appear one space to the right of the array and the subject enters the row number from the keyboard, or (2) the subject touches the target letter with a light pen. Average scanning rate is determined from the slope of the line relating correct response times to target row locations. (FLEXIBILITY OF CLOSURE)

II D. Human Performance Models / Theories

Note: To assure the accurate representation of each model, these descriptions are, to a great extent, presented in the words of the original author(s).

Braune, R. & Foshay, W. R., (1983). Towards a practical model of cognitive/information processing task analysis and schema acquisition for complex problem solving situations. Instructional Science, 12, 121-145.

Introduction

This model proposes an alternative approach to task analysis of complex environments based on human information processing theory. Conventional task analysis fails to promote transference of learning to other tasks when applied to task domains that are too dynamic, complex and lacking in definition of conditions or criteria. Consequently, this model incorporates the theoretical constructs of information processing in developing an appropriate task analysis.

Model Description

The model relies upon three key factors on which the method of task analysis is based, namely, 1) a descriptive model of human performance 2) an understanding of the roles of expectancies in problem-solving, and 3) an understanding of the relationship between expectancies and schemata. The three factors combine to suggest a model of schema acquisition and problem-solving in complex environments which is suitable for information processing task analysis.

A Descriptive Model of Human Performance

The model represents four dimensions which influence an individual's performance: 1) knowledge, 2) cognitive/information processing, 3) physiological state and, 4)motivational/emotional state. Individuals can differ in their capacity along any one of these four dimensions and also within each one of the four by level of competency. It is assumed that individuals can compensate in one dimension if performance capacity in another dimension is not at the requisite level for a given task.

Problem-Solving and Expectancies

A principal component of human problem-solving is the expectancy or goal determination which controls the strategy used for chunking. The way in which stimuli are chunked is a major determinant of success on the problem-solving task.

Expectancies and Schemata

Schema acquisition is a concomitant of perception. This close linkage of schemata and expectancies suggests that the process of problem-solving leads to acquisition of schemata just as does perception.

Schema Theory and Task Analysis

The model introduces the concept of a schema in the context of instructional design. A three-part strategy for information processing task analysis or instructional design is suggested: 1) conducting a concept hierarchy analysis of the task domain by selective positioning of operators based on background knowledge, 2) planning positive and negative example sets to enhance the learner's understanding of individual concepts, and 3) developing a progression of problems which help the learner assimilate the knowledge into existing schema by combining concepts.

An Example of Problem-Solving Task Analysis

The model examines the tasks of judgment and decision-making on both a micro-level and macro-level. The micro-level assesses the concrete perceptual-motor domain. Examples are precision of specific maneuvers or correctness of following a specific procedure. Methods used to gauge this type of performance include observations by check pilots, simulator recording and inflight monitoring systems. The macro-level of judgment examines the abstract tasks of mission planning, execution and situational assessment.

A Model for Schema Utilization and Modification

It is probably true that at the micro-level no generalizable problem-solving process seems to exist. The evidence suggests that at the macro-level a general schema utilization and modification process can be found.

The model represents an attempt to provide a framework upon which instructor-student interaction can be built and which has as its goal the utilization and modification of existing schemata and the creation of new schemata. The model attempts to account for three different kinds of learning proposed by Rumelhart and Norman (1981) namely, 1) accretion, 2) schema evolution , and 3) schema creation. It is also consistent with an approach proposed by Evans (1982) called "problem-oriented instruction". The primary objective of the proposed process is to make overt the learner's problem-solving procedures and to model a process control schema (Kozminsky, Kintsch, & Bourne, 1981) which allows the learner to deal with newly encountered stimulus events.

Discussion

This work attempts to take the findings from information processing research and translate them into a practical approach that can be applied by instructional developers and instructors in complex task domains. One of the problems that can be seen is that explicit procedures must be developed for mapping the simple-to-complex progression of problems. Ultimately, the model also must take into account all four dimensions affecting human performance.

Associated Abilities

An assessment for the tasks associated with this model identified the following abilities:

1. Category Flexibility
2. Deductive Reasoning
3. Inductive Reasoning
4. Perceptual Speed
5. Problem Sensitivity
6. Selective Attention
7. Speed of Closure

Chu, Y. & Rouse, W. B. (1979). Adaptive allocation of decisionmaking responsibility between human and computer in multitask situations. IEEE Transactions on Systems, Man and Cybernetics, SMC-9(12), 769-778.

Introduction

The model described is based on a queueing formulation in which multitask decisionmaking and a threshold policy for turning the computer on/off is proposed. This policy minimizes event-waiting cost subject to human workload constraints. Data was collected to estimate the parameters of a queueing model of pilot decisionmaking in unaided monitoring and control situations. The model gives reasonable predictions of pilot performance in performing subsystem tasks.

Model Description

Rouse (1977) has suggested that a dynamic or adaptive allocation of responsibilities may be the best mode of human-computer interaction. With adaptive allocation, responsibility at any particular instant will go to the decisionmaker most able at the moment to perform the task. The adaptive policy proposed here allocates decisionmaking responsibility so as to optimize system performance by maintaining human workload at appropriate levels. It is proposed that allocation decisions be automated and delegated to a computerized coordinator.

Proposed Algorithm

Rouse (1977) has described human-computer interaction in multitask decisionmaking situations as a queueing system with two servers (human and computer) and K classes of customers. Given this description, the problem of allocating decisionmaking responsibility is simplified to one of determining who serves a particular customer, or to which server should the arriving customer be directed.

Heyman (1968) proposes an optimal threshold policy which has a simple critical number characterization (S,s). This (S,s) policy is to provide no service if the system size, N (number of customers in the queue), is (s) or less, and to turn the server on when the size N is greater than (S). The cost incurred includes waiting cost, running cost, and switching cost.

The optimal threshold policy (i.e., S and s) should vary as the system variables vary. Sources of variation include: (1) traffic demand (arrival rates), (2) server performance and task complexity (task involvement, service rates, and probabilities of error), and (3) system and performance uncertainties (unidentified parameters).

A simulation approach was adopted to determine the optimal stationary policy because analytical procedures for determining the optimal thresholds were judged to be cumbersome.

There are three classes of input variables in the simulation procedure. The first class includes process arrival rates, service rates, and waiting cost rates for subsystem processes. The second class of variables are those specific to the decisionmakers: the probabilities of incorrect actions and missed events, the false alarm arrival rates and service rates, scan times, task switching times, and computer on/off switching times. The third class of variables includes the control limits, S and s. The simulation output supplies statistics for the operational characteristics of interest such as waiting time and severe occupancy.

A Queueing Theory Formulation

A queueing formulation of multitask decisionmaking with two servers (the pilot and the computer) and (K+1) classes of customers (K subsystem events plus control events represented by displayed guidance errors in the manual control mode) was developed. This queueing representation of the flight management task not only provides the features of a time-line analysis of continuous control and performance of discrete-time events, but also provides a basis for: 1) mathematical analysis of control of event arrivals and servicings, 2) flexible representation of time-varying priorities, and 3) ready extension to multiple operator systems.

Discussion

This approach is said to be applicable to multitask situations where system criteria and goals are clear, computer decision aids are desirable, the tasks to be performed are well-structured, and the time delay of discrete events is of major concern. Situations falling into this category include flight management, air traffic control, various industrial process monitoring, and control tasks.

Associated Abilities

An assessment of the tasks associated with this model identified the following abilities:

1. Deductive Reasoning
2. Inductive Reasoning
3. Information Ordering
4. Problem Sensitivity
5. Reaction Time
6. Response Orientation
7. Selective Attention

Levison, W.H. (1982). The optimal control model for the human operator: Theory, validation, and application. Proceedings of the Workshop on Flight Testing to Identify Pilot Workload and Pilot Dynamics (551-579). Edwards AFB, CA.

Introduction

The Optimal Control Model (OCM) is an informational model of the task environment which is based on the assumption that the well-motivated, well-trained human operator will act in a near optimal manner subject to the operator's internal limitations and understanding of the task. The OCM differs from other models of the human operator in the following ways: 1) the methods used to represent human limitations, 2) the inclusion of elements that compensate optimally for these limitations, and 3) the extensive use of state-space concepts and the techniques of modern control theory.

Model Description

Application of the OCM requires specification of the following features of the environment: 1) a linearized state variable representation or model of the system being controlled, 2) a stochastic or deterministic representation of the driving function or environmental disturbances over which the operator must exert control, 3) a linearized "display vector" summarizing the sensory information utilized by the operator (including visual, vestibular and other sources as appropriate), and 4) a quantitative statement of the criterion or performance index for assessing operator/machine performance. (Kleinman, Baron and Levison, 1970).

The OCM is a model for the dynamic response behavior of the closed-loop control system. Because the model is capable of treating multi-variable systems, all system variables are represented as vector quantities. The portion of the model structure designated as "Human Operator Model" contains elements related to the operator's adaptive response behavior and to limitations that constrain this behavior. These model elements are reviewed below in the order corresponding to the flow of information.

The variables are assumed to be corrupted by "observation noise" introduced by the human operator. This noise is analogous to the internal noise level postulated in signal detection theory and provides one means by which the model accounts for human limitations in perceptual resolution, central-processing, and attention-sharing capacity. At this point, the model is dealing with a noisy representation of the displayed quantities. This representation is then delayed by an amount representing internal human processing delays.

The central elements of the model are referred to as the **Kalman estimator** and **predictor**. Their purpose is to generate the best estimate of the current state of system variables, based on the noisy, delayed perceptual information available. These elements compute the estimate of this state so as to minimize the residual estimation uncertainty; they represent the operator's ability to construct from his understanding of the system and his incomplete knowledge of the moment-by-moment state of the system, a set of expectancies concerning the system behavior at the next moment in time. These elements reflect the assumption that the human operator has both an internal model of the dynamics of the system being controlled, and a representation of the statistics of the disturbance driving the system.

Given the best estimate of the current system state, the next model element ("L^*") assigns a set of control gains or weighting factors to the elements of the estimated state, in order to produce control actions that will minimize the defined performance criterion.

Just as an observation noise is postulated to account for perceptual and central processing inadequacies, a motor noise is introduced in the model to account for an inability to generate noise-free control actions. In many applications this noise level is insignificant in comparison to the observation noise, but where very precise control is important to the conditions being analyzed, motor noise can assume greater significance in the model. Finally, the noisy control response is assumed to be smoothed by a filter that accounts for an operator bandwidth constraint. In the model, this constraint arises directly as a result of a penalty on excessive control rates included in the performance criterion. The constraint may mimic actual physiological constraints of the neuromotor system or it may reflect subjective limitations imposed by the operator.

It should be emphasized that the parameter values that must be provided by the investigator correspond to the human limitations that constrain behavior. With these limitations as the constraints within which performance is produced, the model predicts the best that the operator can do.

Note: Although the current presentation includes only a conceptual description, the original paper contains extensive explanation of the mathematical components involved in the model.

Discussion

The OCM has been applied--mostly with regard to aircraft flight--as a predictive and as a diagnostic tool. Areas of application include display design and evaluation, control design and evaluation, prediction of aircraft handling qualities, simulator design and evaluation, effects of environmental stress, and design of experiments.

Associated Abilities

An assessment of the tasks associated with this model identified the following abilities:

1. Control Precision
2. Glare Sensitivity
3. Near Vision
4. Night Vision
5. Time Sharing

Muralidharan, R., Baron, S., & Feehrer, C. (1979). A decision, monitoring, and control model of the human operator applied to an RPV control problem (Tech. Rep. AFOSR-TR-79-0675). Washington, DC: US Air Force Office of Scientific Research.

Introduction

This paper describes application of a decision-making, monitoring and control model (DEMON) of a human operator controlling Remotely Piloted Vehicles (RPVs). The DEMON model is an extension of the Optimal Control Model (OCM) of the operator and was derived by infusing decision theoretic notions into the basic OCM structure. The resulting model is designed to treat situations in which control actions may be infrequent while monitoring and decision-making are the operator's main tasks. The task modelled is a simplified version of an RPV mission.

Model Description

The DEMON model is an example of a top-down or analytic approach to human performance modelling. This approach begins with a mathematical characterization of the task, including the overall goals and the criteria for good performance. Assumptions are then developed regarding the human operator and the system in order to characterize performance in relation to the parameters of interest to system designers.

Theoretical Foundation

DEMON has its roots in control theory, statistical estimation, and decision theory. It draws heavily on the information processing model implicit in the OCM model of the human operator (Baron, 1976). To this information processing structure is added a decision-making structure for modelling discrete monitoring and control decisions and a structure for computing continuous control actions.

Expected Net Gain

The decision-making structure in DEMON incorporates an expected net gain (ENG) concept, which is used as a criterion for making a rational choice among alternatives. The ENG of a particular action is calculated by subtracting the cost of that action from its expected gain. The expected gain itself is the difference between the expected cost of events when no action is taken and the expected cost of events that may arise after this action. The rational choice is to select that action which has the greatest ENG.

Closed-Loop Control System

The DEMON modelling approach views the human operator, during the enroute phase on an RPV mission, as an element in a closed-loop control system. Further elucidation as well as mathematical details for each element of the model are presented by Muralidharan, et al.

Discussion

Experimental use of the DEMON model has yielded results typical of those obtained with a top-down approach to modelling the RPV control model. Results reported for monitoring performance are said to indicate that the model does behave reasonably, that the parameters significantly affect the performance and that the monitoring and patching trends are as expected.
These parameters appear to adequately capture the important aspects of variations in monitoring and

patching strategies. The parameters further demonstrate how the model may address important considerations relevant to the system designer, including RPV/Operator ratio, allowable navigation errors and tolerable reporting errors.

Associated Abilities

An assessment of the tasks associated with this model identified the following abilities:

1. Control Precision
2. Deductive Reasoning
3. Inductive Reasoning
4. Information Ordering
5. Problem Sensitivity
6. Reaction Time
7. Response Orientation

Sanders, A.F. (1983). Towards a model of stress and human performance. Acta Psychologica, 53, 61-97.

Introduction

The model attempts to relate energetical and structural mechanisms of human information processing and to incorporate an interactionally defined concept of stress in human performance research. The model is based upon a linear stage notion of information processing. This approach describes information flow through the organism as a sequence of processing stages mediating the transformation from signals into responses. In accord with Pribram and McGuiness (1975), three energetical supply systems are proposed which are selectively related to specific cognitive processing mechanisms.

Model Description

The model assumes the duration of processing in each stage is affected by the state of the subject as well as by computational demands. Sanders (1981) has briefly described an outline of the model. It relies upon four computational stages in the traditional choice reaction process. These stages are: 1) stimulus-preprocessing (affected by signal intensity), 2) feature extraction (affected by signal quality), 3) response choice (affected by S-R compatibility), and 4) motor adjustment (affected by time uncertainty).

A relevant assumption of the model is that effects of subject's state on processing duration are limited by the extent to which active processes play a role in the cognitive operations of a stage.

Three Types of Energetical Supply

In line with the notion of multiple resources, the processes involved in different stages draw upon different energetical resources. A first resource type is related to motor adjustment, a second to feature extraction and a third to response choice. Stimulus preprocessing is only dependent upon automatic processes and thus does not require a separate energetical resource.

Pribram and McGuinness (1975) consider three systems in the control of attention, namely: (1) an arousal system as a phasic response to input, (2) an activation system as a tonic readiness to respond, and finally (3) an effort mechanism as a coordinating and organizing principle. Effort is supposed to coordinate the activity of arousal and activation, but has in addition the wider function of promoting the competence of the information processing system.

A Model of Stress and Arousal

Coupling neurophysiological notions to those derived from the linear stage model delivers the main elements of this cognitive-energetical linear stage model of human information processing and stress. The cognitive level consists of computational processing stages. The basal mechanisms are coordinated and supervised by effort, which is also directly linked to the central stage of response choice. Apart from direct energetical supply to this stage, effort serves the function of keeping the basal mechanisms at an optimal value. Information about the state of the basal mechanisms is mediated by an evaluation mechanism.

A Cognitive Concept of Stress in Human Performance Theory

Stress will arise whenever the effort mechanism is either seriously overloaded or falls short in accomplishing the necessary energetical adjustments. According to this formulation, stress and effort covary to the extent that continuing high demands on effort without sufficient success in maintaining or restoring an equilibrium are supposed to constitute the basis of stress responses. Thus, allocating effort does not evoke stress per se. It is the presence or the threat of a lasting disturbance of the equilibrium which is essential. Stress may arise because effort fails in correcting the effects of too high or too low a level of arousal; too high or too low a level of activation; or finally, there may be failures in the supply of sufficient energetical resources to reasoning and decisionmaking processes. This implies at least five patterns of stress. The converging element of these patterns is a deviant state of the evaluation system, which may cause a common subjective feeling of stress.

Discussion

In agreement with several recent suggestions (e.g., O'Hanlon 1981) this model shares the deduction that subjects who show high levels of performance under suboptimal conditions are most under stress. They appear to continually allocate effort to arousal and/or activation, thereby counteracting a decrement or a low performance asymptote.

It is concluded that performance measures are not effective indicants of stress. They are only needed as a control measure to ensure that sufficient effort is allocated to keep performance at the optimum. The stress response must be measured in physiological and/or hormonal patterns as reflections of the overdemands on effort. Problems of underarousal, underactivation and their combined occurrence are most easily investigated by way of such techniques.

Associated Abilities

An assessment of the tasks associated with this model identified the following abilities:

1. Control Precision
2. Flexibility of Closure
3. Perceptual Speed
4. Reaction Time
5. Response Orientation
6. Selective Attention
7. Speed of Limb Movement

Wherry, Jr., R. J. & Curran, P. M. (1966). A model for the study of some determiners of psychological stress: Initial experimental research. Organizational Behavior and Human Performance,1, 226-251.

Introduction

During critical periods of a mission, susceptibility to anticipatory physical threat may be the decisive factor between success or failure of the mission, and the life or death of the pilot. The authors postulate that the real issue in threat research is the manner in which the individual perceives the environment.

Model Description

According to the anticipatory physical threat stress (APTS) model, there are three major determiners of the amount of stress generated. It is said that most, if not all, of the variance of what is generally understood by the concept of "threatening" can be subsumed under these three elements:

(1) The perceived probability that the event (E) will occur (P'). The important point here is that APTS is a function of the perceived probability that the unpleasant event will occur (P') as opposed to the true probability of its occurrence (P). P' is a composite of at least three evaluations which the individual may make. The first of these is the perceived probability that the event will occur attributable to self performance (P'_s), which is a multiplicative function of the individual's perceived quality of performance (Q'_s) and the perceived relevance of such performance to occurrence of the event (R'_s). A second contributor to P' is the perceived probability of event occurrence attributable to other members of the "team" (P'_o), in cases where several subjects' performances determine the success or failure of a mission. P'_o is hypothesized to be a multiplicative function of the individuals perception of the relevance of their performance to event occurrence (R'_o). The final contributor to P' is the perceived probability of event occurrence attributable to uncontrollable or chance factors (P'_u).

The foregoing statements have been summarized in equation form as follows:

$$
\begin{aligned}
APTS &= f_1(P')\\
P' &= f_2(P'_s + P'_o + P'_u),\\
P' &= f_3(Q'_s \times R'_s),\\
P'_o &= f_4(Q'_o \times R'_o), \text{ and}\\
APTS &= f_1(f_2(f_3(Q'_s \times R'_s) + f_4(Q'_o \times R'_o) + P'_u).
\end{aligned}
$$

(2) The perceived proximity of the event (X') includes temporal, spatial, and psychological proximity. The latter two are undoubtedly confounded with temporal proximity in most cases, however, APTS considers only temporal aspects of the event. Proximity, in its broadest interpretation, indicates the perceived "closeness" of the event.

Some of the temporal aspects of proximity are the perceived time until the event will occur (if it does occur) (T'_E), the time elapsed since the subject was given a warning that the event might occur (T'_w) and the perceived time since the mission (or situation) began (T'_s). As the unpleasant event gets "closer" to the subject (i.e., T'_E gets smaller) it is hypothesized that the anticipatory stress generated will increase, i.e.,

$$APTS = f_6(1/T'_E).$$

(3) The perceived unpleasantness of the event if it occurs (U') is hypothesized to be a function of at least three evaluations which the subject will make. These are the perceived duration of incapacitation if the event occurs (D'_i),the perceived duration of pain if the event occurs (D'_p), and the perceived unpleasant effect the event will have on others whose welfare is important to the subject (U'_o). It is hypothesized that these three evaluations summate to yield the overall unpleasantness of the event. Thus,

$$\text{APTS} = f_7(U'),$$
$$U' = f_8(D'_i + D'_p + U'_o).$$

All three of the preceding evaluations are hypothesized to be a function of the perceived intensity of the event (I'), the perceived duration of the event (D'_E), and the perceived area of the subject that will be hurt if the event occurs (A'). Thus,

$$(D'_i + D'_p + U'_o) = f_9(I', D'_E, A').$$

The composite APTS model is hypothesized to take the form:

$$\text{APTS} = f(P' \times X' \times U').$$

In addition, derivations of this model are set forth to account for : (1) situations in which there are no other "team" members, (2) situations where the subject perceives his performance is not relevant to event occurrence, and (3) whether all subjects were tested under identical event duration (D') and area of self to be hurt (A').

Discussion

The model points out the importance of the role of perception in threat studies. The model predicts that one's perception of proximity of the unpleasant event will determine the amount of threat present.

Experimental use of the model has yielded several findings: (1) confirmation of the hypothesis that mild stress can be enhancing to performance, while larger amounts of stress can cause decrement, (2) a significant effect of past experience-- it appears that confirmation of one's expectations about event occurrence will reduce performance deterioration in subsequent situations, (3) even when the amount of threat is carefully equated for all subjects, some will be more susceptible to stress effects than will others.

Associated Abilities

An assessment of the tasks associated with this model identified the following abilities:

1. Deductive Reasoning
2. Inductive Reasoning
3. Problem Sensitivity
4. Reaction Time
5. Response Orientation

Wickens, C.D. (1980a). The multiple resources model of human performance: Implications for display design (Contract N-000-14-79-C-0658). Arlington, VA: Office of Naval Research.

see also:
Wickens, C.D. (1984). Engineering psychology and human performance. Columbus, Ohio: Merrill.

Introduction

The multiple-resource model asserts that instead of one central "pool" of resources with satellite structures, humans possess several different capacities with resource properties. Tasks will interfere more if more resources are shared. This position has received explicit theoretical development within the framework of the performance operating characteristic (POC) by Navon and Gopher (1979). Wickens (1980) has argued that resources may be defined by three relatively simple dichotomous dimensions. There are two stage-defined resources (early versus late processes), and two modality-defined resources (auditory versus visual encoding), and two resources defined by processing codes (spatial versus verbal).

Model Description

To the extent that any two tasks demand separate rather than common resources on any of the three dimensions, three phenomena will occur: (1) time-sharing will be more efficient, (2) changes in the difficulty of one task will be less likely to influence performance of the other, and (3) the POC constructed between the tasks will be of a "boxlike" form because resources withdrawn from one task cannot be used to advantage by the other, since they are dependent upon different resources.

Stages

The resources used for perceptual and central-processing activities appear to be the same, and these are functionally separate from those underlying the selection and execution of responses. Evidence for this dichotomy is provided when the difficulty of responding in a task is varied and this manipulation does not affect performance of a concurrent task whose demands are more perceptual in nature.

Modalities

Humans can sometimes divide attention between the eye and ear better than between two auditory channels or two visual channels. That is, bimodal time-sharing is better than intra-modal. Poor time-sharing with intra-modal displays can, therefore, be expected if the two visual sources are spatially separated so that both cannot access foveal vision simultaneously or if the two auditory sources mask each other.

Processing Codes

Spatial and verbal processes, whether functioning in perception, working memory or response stages, are said to depend upon separate resources. The separation of spatial and verbal resources seemingly accounts for the high degree of efficiency with which manual and vocal outputs can be time-shared, assuming that manual responses are usually spatial in nature and vocal ones are verbal.

Discussion

The three dimensions of the multiple-resource model are not intended to account for all structural influences on dual-task performance and time-sharing efficiency. They indicate three major dichotomies that can account for a large portion of these influences and can be used by the system designer.

There are many ways in which two tasks can be similar that influence the efficiency of their time-sharing but are not accounted for by the three dimensions. These include several factors: (1) two tasks may have different timing requirements--tasks with different rhythmic requirements are hard to time-share, (2) manual control tasks with different control dynamics reduce time-sharing efficiency, and (3) two tasks may have similar processing elements--two tasks that use both digits and letters will be more easily time-shared than two tasks using the same material. Two tracking tasks that use horizontal and vertical axes, respectively, will be better time-shared than two tasks using the common direction.

Associated Abilities

An assessment of the tasks associated with this model identified the following abilities:

1. Auditory Attention
2. Control Precision
3. Memorization
4. Rate Control
5. Reaction Time
6. Response Orientation
7. Selective Attention
8. Spatial Orientation
9. Time Sharing

II E. Task Source References

Task	Cited Source(s)
Absolute Difference Calculation (IPPB)	
Activities Interest Inventory (PORTA-BAT)	
Alpha-Numeric Visual Vigilance (UTC-PAB)	Hord, 1982
Arithmetic Computations (MTPB)	
Arithmetic Speed (TASKMASTER)	
Auditory Digit Span (NAVAL CCT)	
(Visual and) Auditory Grammatical Reasoning (NAVAL CCT)	
(Visual or) Auditory Serial Addition (NAVAL CCT)	
Auditory-Spatial Sternberg (IPPB)	Sternberg, 1969
Auditory-Verbal Sternberg (IPPB)	Sternberg, 1969
Automatic Aircrew Personality Profiler (PORTA-BAT)	
Blinking Lights Monitoring (MTPB)	
Choice Reaction Time (NAVAL CCT)	
Code Lock Solving (MTPB)	
Code Substitution (APTS)	
Code Substitution (NAVAL CCT)	
Code Substitution (UTC-PAB)	Wechsler, 1958
Continuous Performance (NES)	Rosvold, Mirsky, & Sarason, 1956
Continuous Recall (CTS)	Hunter, 1975
Continuous Recall (UTC-PAB)	Hunter, 1975
Critical Instability Tracking (IPPB)	Jex, McDonnel, & Phatak, 1966

Task	Cited Source(s)
Decision Making Speed (PORTA-BAT)	
Dichotic Listening (IPPB)	Gopher, 1982
Dichotic Listening (UTC-PAB)	Griffen & Mosko, 1985, 1982
Digit Recall (WRAIR-PAB)	
Digit Span (NES)	Wechsler, 1955, 1945
Dot Estimation (PORTA-BAT)	
Embedded Figures (IPPB)	
Embedded Figures (PORTA-BAT)	
Encoding/Decoding (WRAIR-PAB)	Haslam, 1981
Encoding Speed (PORTA-BAT)	
Four-Choice Serial Reaction Time (UTC-PAB)	Wilkinson & Houghton, 1975
Four Choice Serial Reaction Time (WRAIR-PAB)	Wilkinson & Houghton, 1975
Free Recall of Word List (TASKMASTER)	
Grammatical Reasoning (APTS)	
Grammatical Reasoning (CTS)	Baddeley, 1968
Grammatical Reasoning (TASKMASTER)	
Grammatical Reasoning-Traditional (UTC-PAB)	Baddeley, 1968
Grammatical Reasoning-Symbolic (UTC-PAB)	
Grammatical Reasoning with Reaction Time (TASKMASTER)	
Hand-Eye Coordination (NES)	
Hand Steadiness (TASKMASTER)	
Immediate/Delayed Memory (PORTA-BAT)	
Interval Production (CTS)	Michan, 1966

Task	Cited Source(s)
Interval Production (UTC-PAB)	
Item Recognition (PORTA-BAT)	
Linguistic Processing (CTS)	Posner & Mitchell, 1967
Linguistic Processing (UTC-PAB)	Posner & Mitchell, 1967; Shulman, 1974; Craik & Trilving, 1975
Linguistic Processing-Choice Reaction Time (UTC-PAB)	as above for each individual task
Logic Task (NAVAL CCT)	
Logical Reasoning (WRAIR-PAB)	Baddeley, 1968
Manikin (APTS)	
Manikin (NAVAL CCT)	
Manikin (UTC-PAB)	Reader, Benel, & Rahe, 1981
Math Test (NAVAL CCT)	
Mathematical Processing (CTS)	
Mathematical Processing (UTC-PAB)	Shingledecker, 1984
Matrix Rotation (UTC-PAB)	
Maze Task (NAVAL CCT)	
Maze Tracing (IPPB)	
Memory Scanning (NES)	Sternberg, 1969
Memory Search (CTS)	Sternberg, 1969
Memory Search (UTC-PAB)	Sternberg, 1969
Mental Rotation (PORTA-BAT)	
Mood-Activation (WRAIR-PAB)	Thayer, 1967; Zuckerman, Lubin, Vogel, & Valerius, 1964
Mood Scale II (WRAIR-PAB)	Ryman, Biersner, & Rocco, 1974
Mood Scales (NES)	McNair, Lorr, & Droppleman, 1971

Task	Cited Source(s)
Moving Landolt C (APTS)	
Noise Fusion (TASKMASTER)	
Non-Preferred Hand Tapping (APTS)	
Paired Associate Learning (NES)	Wechsler, 1945
Pattern Comparison (NAVAL CCT)	
Pattern Comparison-Simultaneous (UTC-PAB)	Klein & Armitage, 1979
Pattern Comparison-Successive (UTC-PAB)	Thorne, Genser, Sing, & Hegge, 1985
Pattern Memory (NES)	Acker, 1982
Pattern Recognition (APTS)	
Pattern Recognition (NES)	
Pattern Recognition I (WRAIR-PAB)	
Pattern Recognition II (WRAIR-PAB)	
Perceptual Speed (PORTA-BAT)	
Preferred Hand Tapping (APTS)	
Probability Monitoring (CTS)	Chiles, Alluisi, & Adams, 1968
Probability Monitoring (MTPB)	
Psychomotor Device Tests (PORTA-BAT)	
Questionnaire Tests (TASKMASTER)	
Reaction Time (APTS)	
Reaction Time (TASKMASTER)	
Response Alternation (TASKMASTER)	
Risk Taking (PORTA-BAT)	
Second Order Tracking (IPPB)	
Self-Crediting Word Knowledge (PORTA-BAT)	

Task	Cited Source(s)
Serial Add/Subtract (WRAIR-PAB)	Wever, 1981, 1979
Short-Term Memory (UTC-PAB)	
Simple Reaction Time (NES)	
Six-Letter Search (WRAIR-PAB)	Folkard, Knauth, Monk, & Rutenfranz, 1976
Spatial Processing (CTS)	Chiles, Alluisi, & Adams, 1968
Spatial Processing (UTC-PAB)	Chiles, Alluisi, & Adams, 1968
Spoke Task (NAVAL CCT)	
Sternberg (APTS)	
Sternberg Memory Scanning (NAVAL CCT)	
Sternberg-Tracking (UTC-PAB)	Wickens & Sandry, 1982
Stroop (UTC-PAB)	Stroop, 1938; Flowers & Stoup, 1977
Stroop-Like Color Naming (NAVAL CCT)	
Symbol-Digit Substitution (NES)	Wechsler, 1955
Target Identification (MTPB)	
Time Estimation (TASKMASTER)	
Time Estimation (WRAIR-PAB)	Seppala & Visakorpi, 1983
Time Sharing (PORTA-BAT)	
Time Wall (UTC-PAB)	Jerison & Arginteau, 1958; Seppala & Visakorpi, 1983
Two-Column Addition (WRAIR-PAB)	Ekstrom, French, Harman, & Derment, 1976
Two-Hand Tapping (APTS)	
Two-Letter Search (WRAIR-PAB)	Folkard, Knauth, Monk, & Rutenfranz, 1976
Unstable Tracking (CTS)	Jex, McDonnel, & Phatak, 1966

Task	Cited Source(s)
Unstable Tracking (UTC-PAB)	
Visual (and Auditory) Grammatical Reasoning (NAVAL CCT)	
Visual Probability Monitoring (UTC-PAB)	Chiles, Alluisi, & Adams, 1968
Visual Retention (NES)	Lezak, 1976
Visual Scanning (UTC-PAB)	Neisser, 1963
Visual Scanning (WRAIR-PAB)	
Visual or Auditory Serial Addition (NAVAL CCT)	
Visual-Spatial Sternberg	Sternberg, 1969
Visual-Verbal Sternberg (IPPB)	Sternberg, 1969
Vocabulary (NES)	Jensen, 1980
Warning Lights Monitoring (MTPB)	Chinn & Alluisi, 1964
Zip Code Typing (TASKMASTER)	

III. Summary and Conclusions

This project has demonstrated the utility of a cross-referenced tabulation of performance abilities and performance assessment tasks in illuminating the state-of-the-art in each of these areas. This approach affords the performance researcher a rapid-access mechanism for locating both the theoretical research and the laboratory performance data related to a particular ability. Additionally, the **Ability Catalog** provides an indication of the kinds of performance measures and theories in need of further development. A discussion of identified shortfalls and suggestions for improvement follow.

First, we find that a number of abilities are over-represented in terms of the number of measures that are used to assess them. Consider, for example, "Perceptual Speed" which is the ability to compare objects and patterns quickly and accurately. Our survey indicates that this construct has been isolated in eight separate batteries and is implicated in no less than forty-two assessment tasks. This suggests several possibilities: (1) certain abilities are not unitary, or at least do not constitute an exclusive category, (2) there is an abundance of tasks that measure different things but which are not themselves unitary, i.e., one task may tap multiple abilities, or (3) task battery development has progressed asymmetrically with examples of over- and under- representation in evidence. It seems likely that each of these suppositions is accurate to some extent.

In general, it appears that current computerized performance assessment batteries measure those characteristics that they are most facile at measuring--e.g., reaction time, perceptual speed, memorization--regardless of the meaningfulness of such measurement for real-world application. In the UTC-PAB, for example, "Memorization" is a requisite ability for performance on five separate tasks, "Perceptual Speed" an element of twelve tasks, and "Response Orientation" a component of four tasks. On the other hand, this battery, which represents a Tri-Service effort to develop the state-of-the-art in computerized performance assessment, offers no measure of "Problem Sensitivity"--the ability to quickly recognize the occurrence of a problem--certainly a critical ability for on-the-job performance in most environments. Similarly, by reference to Section II B it may be seen that the Communication domain of abilities (see Table 2) is under-represented in the batteries reviewed, and the Physical domain has been virtually ignored--presumably because these abilities are less amenable to microcomputer assessment. In sum, it can be argued that microcomputer task battery development has emphasized such issues as psychometric acceptability and/or administration convenience instead of developing a tool with which to comprehensively examine the span of abilities which constitute human performance. Thus, we have a plethora of tasks with which to measure reaction time, but a paucity of measures assessing "Originality", "Fluency of Ideas", or "Problem Sensitivity".

More than half of the abilities examined--twenty-seven of fifty-two--were not represented by any

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microcomputer-administered task. While a number of these (e.g., "Stamina" and "Sound Localization") may not be suitable for assessment by microcomputer, they are no less critical for job performance in specific work environments. Due to the limitations inherent in the microcomputer format, then, comprehensive assessment of the full range of human abilities related to many jobs requires that other assessment techniques be employed as complements to a microcomputer-based task battery .

In addition to Fleishman and his associates, taxonomies of work situations or work environments have been presented by a number of authors. One of the most developed of these is that of Holland (1985) in which six task types are presented:

Realistic- mechanical or technical tasks
Intellectual- tasks requiring generation or verification of knowledge
Artistic- creative or aesthetic tasks
Social- personal contact or interpersonal tasks
Enterprising- manipulative or persuasive tasks
Conventional- routine or precise tasks.

While the majority of real-world tasks fall into the *Realistic* category, most tasks are also composites of these task types. For example, a particular task may be primarily *Realistic*, but may have significant *Social* and *Enterprising* components.

The Fleishman abilities requirements approach, upon which the present effort is based, seems primarily oriented to the *Realistic/Conventional* task types. The cognitive/perceptual/psychomotor skills that predominate this approach as well as the associated tasks which populate the microcomputer batteries reflect this emphasis. Conversely, we find that the social, persuasive, and, to some extent, the creative types of abilities are largely absent from consideration. Thus, it can be argued that a large domain of work settings and a number of performance abilities have been overlooked in the current abilities requirements approach, which, of course, weakens our predictive capabilities with respect to such settings.

Another area shown by the present effort to be in need of more intensive inquiry is that of team performance. With the single exception of the Code-lock Solving task on the MTPB, no such "group" emphasis was seen in any of the reports reviewed during the current project. The emphasis given to team performance by both model and task battery creators alike should, of course, reflect the incidence of such performance in the real-world. Again, it is the task analysis of these jobs (i.e., the third element of the proposed research program) which will provide the requisite information. It is fully expected, however, that, similar to consideration of "Problem Sensitivity", the issue of team or group performance (as well as the related issue of team/group training) is in need of substantially increased investigation.

Laboratory task batteries, then, need to more accurately reflect the abilities requirements of actual jobs. Future efforts in the current research program will likely find similar discrepencies (albeit between/among different elements) when evaluating the relative emphases of abilities in jobs versus that in performance models. Regrettably, this is not a new problem. In 1970 Dudek expressed the need to make human factors research data "...inter-comparable and more meaningful to direct application." This need still exists.

On the other hand, Dudek (1970) also called for "... the standardization of tasks and measures used in human factors research to assure comparable results from study to study..." Our review indicates that considerable advances have been made in this area. The best example is, perhaps, the UTC-PAB, which, as suggested by its name (Unified Tri-Services...), represents a concerted, cooperative effort to achieve such standardization. Fortunately, the impact of these standardization efforts will extend well beyond the U.S. military since the UTC-PAB, as well as its predecessors, the CTS, WRAIR-PAB, and PETER/NAVAL CCT batteries are available for use by researchers in the private sector. An interesting sidelight to the standardization issue is the apparent acceptance of the IBM PC as the "standard" for performance battery implementation. The UTC-PAB is being written for IBM-PCs while the CTS, WRAIR-PAB, and Taskmaster batteries are either being converted to or additionally written for IBM equipment.

The recommendations made as a result of the current effort are "expansive" in nature. That is, we believe that this approach has been validated and that we must now add to this scheme:

a) the real-world job task analysis information;
b) more performance models/theories--with appropriate distinctions made between them (per Meister,1985); and
c) a validation of the subjective ability/task judgments made in the **Ability Catalog** accomplished through a quantitative evaluation of the link between specific performance abilities and assessment instruments.

Finally, we may need to consider use of other ability taxonomies in addition to that of Fleishman & Quaintance. While this taxonomy defines the most extensive list of abilities, its origin and, therefore, its primary strength, is in the psychomotor domain. As systems impose increasing cognitive and decreasing physical demands on operators, it will be necessary to thoroughly catagorize the human cognitive abilities utilized in these jobs. Indeed, Braune & Foshay (1983) propose that we may need to refine our traditional task analytic approach in order to understand performance in "highly dynamic complex environments" such as aviation and nuclear power plant operations. A taxonomic scheme such as that used by Allen, et al. (1978) or Guilford's *Structure of Intellect* (Guilford & Hoepfner, 1971) which "...remains the most complete taxonomic system for describing intellectual functioning" (Fleishman & Quaintance, 1984), may prove to be of great value in catagorizing and understanding the role of cognitive abilities in these new dynamic, complex jobs. Performance assessment batteries and performance models/theories must reflect this change in emphasis toward such issues as "Problem Sensitivity" and away from "Reaction Time". It is hoped that this *Directory* and its subsequent revisions will aid this process.

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